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Photovoltaic Programme Edition 2008
Summary Report, Project List, Annual Project Reports 2007 (Abstracts)

elaborated by:
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Cover:

Zero-Energy Building: Support Office of Marché International, Kemptthal / ZH

44,6 kWp Solar Power System with Thin Film Solar Cells

(Photos: Front cover: SunTechnics Fabrisolar, Back cover: Büro für Architektur Beat Kämpfen, Photo Willi Kracher)

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Federal Department of the
Environment, Transport, Energy and Communications DETEC

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PHOTOVOLTAICS PROGRAMME

Summary Report on the Research Programme 2007

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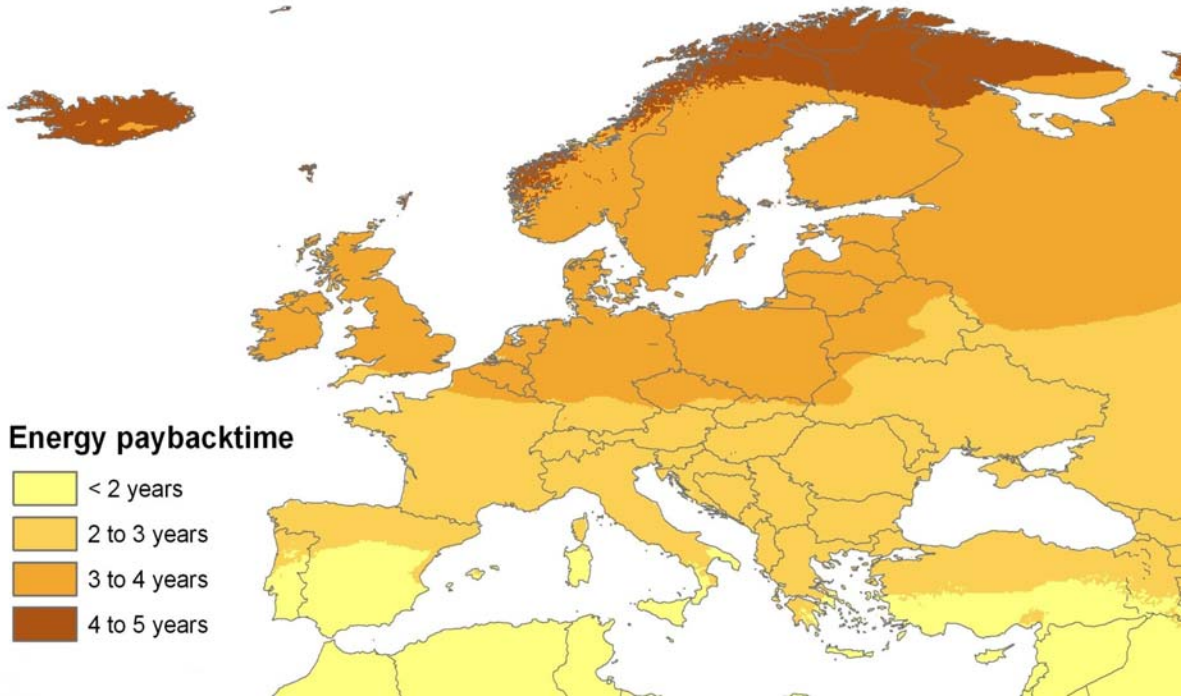

Energy paybacktime for photovoltaics - a question asked again and again:

Within the framework of revision of the photovoltaics data in the Ecoinvent database, *ESU Services* determined the energy paybacktime for photovoltaics on the basis of current industrial processes and products. This representation shows the energy payback time of a multicrystalline, 3 kWp, sloping roof installation in Europe with the UCTE electricity mix as a reference (source: *ESU Services*).

Contents Summary Report

1. Programme priorities and targets

Photovoltaics enjoyed a further upswing in 2007 both world-wide as well as in Switzerland. This also affected the Photovoltaics Programme in a big way, in that more and more industrial players took a look at photovoltaics, formulated ideas and concepts and developed projects. As a result of the cost-covering remuneration for power from renewable energy sources decided on by parliament at the beginning of the year, application-oriented questions became additionally important. The previous level of activities was able to be held as a result of the wide support for the programme to be found in the research area. Continuing growth in the international photovoltaics market provides an important basis for the clear expansion of the industrial basis for photovoltaics that is still to be seen in Switzerland.

Thus, the Photovoltaics Programme has remained closely oriented towards industrial implementation and international competitiveness, both for products and for the preceding research activities. In 2007 about 55 research and development activities including remaining P+D projects were running, taking into account all known projects receiving support from the public authorities.

Based on the Energy Research Master Plan of the Federal Energy Research Commission (CORE) [61], the main objectives of the Swiss Photovoltaics Programme for the period 2004 to 2007 are [62]:

- Further cost reductions (≠ prices) in photovoltaics energy systems (typical values for 2007: 2.5 CHF/Wp for modules; 5 CHF/Wp for complete systems) and corresponding improvements in the electrical properties of individual components (2007: thin film modules with >12 % efficiency), production costs and industrial production;
- Establishment and consolidation of the industrial basis for photovoltaic products, including solar cells and modules in selected technological areas;
- High level of integration and standardisation of products and systems for mass markets.

The Photovoltaics Programme is therefore divided into the following five sections:

SOLAR CELLS OF THE FUTURE

As before, work on **thin film solar cells** continued to focus on these principal areas: **silicon** cells (amorphous, micro-crystalline), cells based on **compound semiconductors** (CIGS); and **dye cells. New concepts** for long-term technology options (materials and processes) e.g. organic and polymer cells, are gaining importance in the basic research area, and, at the same time, are moving away from pure concepts to the production of actual solar cells. The industrialisation of manufacturing processes is being pursued intensely and is, for silicon thin film solar cells, at an advanced stage; for compound semiconductors, an industry project is being set up. In 2007, concrete plans for large production plants in Switzerland for thin-film silicon solar cells were announced for the first time. Solar cells on flexible substrates are still becoming increasingly important.

MODULES AND BUILDING INTEGRATION

The **integration of photovoltaics** in the built environment still continued to be the main focus of current applications. Whilst the market now offers a broad range of mounting systems, new products for building integration based on thin film cells, together with the experience gained in this area, was a topic of continued and growing importance.

ELECTRICAL SYSTEMS TECHNOLOGY

Quality assurance for photovoltaic modules, power inverters and entire systems, together with the **long-term observation** of these components, are topics of high relevance for practical applications and are being worked on in appropriate competence centres at universities of applied science. Long-period measurements and the increased analysis of abnormal functioning of individual components are required to determine critical parameters and to extend service life. Based on this system-relevant work, the objective is to further increase the specific energy yield of photovoltaic installations (kWh/kWp). For **island installations,** the combination of photovoltaics with other energy technologies in hybrid installations is becoming increasingly important.

FURTHER PROJECTS AND STUDIES

Studies in this area are to provide basic information on general questions in connection with the development of the market for photovoltaics. These concern in particular the **potential**, **environmental aspects,** and **energy planning** and practical **help** for the planning and supervision of installations. For this, the latest Internet technologies, computer models, image processing, geographical information systems and even satellite communications are being used. On the other hand, for applications in **developing countries** non-technical aspects have high priorities. This area of the programme also includes activities at the interface to other energy technologies.

INTERNATIONAL INSTITUTIONAL CO-OPERATION

International co-operation forms an important aspect in all areas of work. Remaining abreast of international developments and an intensified exchange of information within the **EU** and **IEA** programmes were important objectives that were further pursued during the reporting period. Successful international co-operation was continued in some of the larger EU projects (IP - Integrated Projects). Moreover, Swiss participation in European networks (**PV-ERA-NET** and **European Photovoltaics Technology Platform**) was of overriding importance in the year under review. Here, the publication the Strategic Research Agenda for Photovoltaic Solar Energy Technology [63] by the European Photovoltaics Technology Platform is to be especially emphasised.

2. Work completed and results achieved in 2007

CELL TECHNOLOGY

In the 2007 reporting period, a **wide spectrum of Swiss solar cell research** was successfully pursued thanks to wide support for research. Participation in EU projects included in the 6th framework programme for research as well as in CTI projects are considered as being important elements here. In the meantime, Switzerland is directly or indirectly participating in most of the current integrated projects of the European Commission in the photovoltaics area.

a) Thin film silicon

The University of Neuchâtel (IMT), the EPFL (CRPP), the Haute Ecole Arc ingénierie (Le Locle), and the NTB (Buchs), together with the companies *oerlikon solar* (Trübbach and Neuchâtel) and *VHF-Technologies* (Yverdon), are pursuing developments in the thin film silicon field, and represent the most important mainstay of the Photovoltaics Programme.

During the year under review, the IMT at the University of Neuchâtel finished the current phase of work on its **thin-film silicon solar cells** project [1]. The objectives of this SFOE project are to increase the efficiency of solar cells on different substrates (goal of 14 % for micromorphous solar cells) further, to continue to develop the processing and characterisation of solar cells and to ensure that the necessary infrastructure (processes, manufacture and characterisation) to support the industrial partners exists. Therefore, various deposition systems were renewed and automated, the systems for the characterisation of solar cells are being standardised, and particular emphasis is being placed on the reproducibility of the individual production steps. Co-operation with industry occurred primarily with *oerlikon solar* and *VHF-Technologies*, who are implementing the processes developed at the IMT in their products. The following results were achieved in the year under review:

On the basis of the results of the previous years on amorphous and microcrystalline silicon, single junction solar cells on glass substrates and the development of intermediate reflector layers, a further increase in the efficiency of micromorphous solar cells was striven for. After the intermediate reflector layers built up to now on ZnO, intensive work involving SiOx layers was carried out in the year under review. Using this material, micromorphous solar cells with a surface area of 1.2 cm^2 achieved an initial efficiency of 12.6%. in the year under review. Both amorphous and microcrystalline solar cells of high quality were produced on plastic substrates. Microcrystalline solar cells on PET (polyethylene terephthalate) and PEN (polyethylene-naphtalate) attained an efficiency of 8.6%. The physical understanding of the opto-electronic properties of ZnO, in particular the influence of grain boundaries in the material on the mobility of the charge carriers, was improved. A new, automated, double-chamber deposition system was successfully put into operation (Fig 1).

A new CTI project, ***Flexible Photovoltaics - Next generation high efficiency and low cost thin film silicon modules*** [2] was begun in the year under review involving the IMT at the University of Neuchâtel and *VHF-Technologies.* In this project, the goal is to significantly increase the efficiency of around 4.5% obtained up to now with *VHF-Technologies* initial flexible solar cell generation. By the introduction of a diffusely-scattering, backside reflector and an amorphous cell structure in tandem configuration, the efficiency of the industrial products is to be raised to 6%. First promising results with an efficiency of 8.8% on a small surface area have been achieved.

In a new ***THIFIC*** project***, Thin film on crystalline silicon*** [3], sponsored by the Axpo Natural Power Fund, ultra-high efficiency solar cells with efficiencies of 20-22% are being worked on at the IMT. Here, the well-known concept of a hetero-junction of crystalline silicon solar cells and amorphous or microcrystalline solar cells is being used (HIT cell). The advantages lie in the use of thin silicon wafers with a thickness down to around 100 µm and the corresponding material and energy savings. In preparatory work for this project, an efficiency of 19% has already been achieved. Work now goes on to achieve even better results using textured wafers.

Together with further partners in the EU, IMT and *VHF-Technologies* are taking part in the EU's ***FLEXCELLENCE*** project [4] on the topic of flexible solar cells on plastic and metal substrates whereby the overall co-ordination of the project is in the hands of the IMT. In the year under review, nano-textured substrates on metal and plastic films were produced. In this project, three different approaches are being examined for roll-to-roll deposition, in particular microwaves PECVD (Plasma Enhanced Chemical Vapour Deposition), Hot Wire CVD (Chemical Vapour Deposition) and VHF PECVD. IMT and *VHF-Technologies* are concerned with the last one of the three procedures mentioned. At the IMT, a micromorphous tandem cell on plastic with an efficiency of 10.9% was manufactured in the year under review using PECVD. On this basis, costs below 0.6 €/Wp and an efficiency of 10% should be able to be achieved in the industrial manufacturing context.

In the integrated EU project ***ATHLET*** [5] IMT *and oerlikon solar* are concerning themselves with the further development of thin-film silicon solar cells. For micromorphous tandem cells, a stable efficiency of 10%, a surface area of 1 m^2 and 10 Å/s deposition rate are being aimed for along with module production costs of <0.5 €/ Wp. This project complements the SFOE project at the IMT mentioned above. In the KAI-S reactor, an initial efficiency of 10.5%. was achieved in the year under review. *oerlikon solar* demonstrated their first, large-area (1.3 x 1.4 m^2) micromorphous modules with an efficiency of 9.46% at the 22nd European Photovoltaics Conference in Milan.

Figure 1: *Automated thin-film silicon dual-chamber deposition system on the basis of oerlikon solar's KAI-M plasma box (photo: IMT)*

Figure 2: *MRC sputterer for the deposition of the front and rear contacts on 30 x 30 cm^2 CIGS thin-film solar cells (photo: ETHZ)*

b) Crystalline silicon

In the CTI's ***SIWIS*** project [6], EMPA Thun, in co-operation with *Applied Materials Switzerland* (formerly *HCT Shaping Systems)* investigated the mechanisms which can lead to surface defects when wire-sawing thin silicon wafers in order to develop corresponding models. The main objective of the project is the production of wafers with a thickness of less than 100 µm for the manufacturing of crystalline silicon solar cells. As a function of the saw parameters, a correlation between the surface roughness and the formation of fissures and mechanical stability was found. In spite of the conclusion of the work within the framework of the CTI project, the partners intend to continue co-operation.

In a new CTI feasibility study called ***SIRE*** [7] the University of Applied Sciences in Geneva together with *Applied Materials Switzerland* is examining the possibilities for the recycling of silicon from sawing wastes. It could be shown that the silicon can be separated from silicon carbide.

The EU's ***BITHINK*** project [8], run by *Applied Materials Switzerland,* was concluded in the year under review. Here, wafer thickness could be reduced from 280 down to 90 µm. This leads to a number of wafers per meter of solid silicon of approximately 3500 or 1.45 m^2 silicon wafer per kg silicon. For a bi-facial solar cell and 13% efficiency, this leads to a silicon consumption of 3.9 - 4.6 g/Wp. If the efficiency can be increased to 15%, values under 4 g/Wp are possible.

c) II-VI compounds (CIGS)

The Thin Film Physics Group at ETHZ has been working on EU projects involving solar cells based on compound semiconductors (CIGS, CdTe) for many years now. The SFOE project ***Large area flexible CIGS*** [9] that has followed the earlier ***FLEXCIM*** project examined the up-scaling of CIGS solar cells onto larger flexible substrates. On the one hand, the vacuum deposition equipment necessary is to be improved; on the other hand, the efficiency and the reliability of the CIGS solar cells is to be improved too. An efficiency of 12% on polyimide substrates is being aimed for. Further, alternative back-side contacts are to be developed. An important point with respect to large-area deposition is a sufficiently uniform distribution of the layer qualities (e.g. layer composition, layer thickness) over the surface of the substrate. On a surface of 30 x 30 cm^2, a standard deviation of 2 - 6% was achieved in layer composition and layer thickness. First complete solar cells on the same surface achieved an efficiency of more than 8%, whereby the reproduction of these values has still to be improved (Fig. 2).

In a new SFOE project ***Thin film CIGS solar cells with a novel low cost process*** [10], the Thin Film Physics Group is developing a completely novel production process for CIGS solar cells. Making use of an ion-exchange reaction, copper from a diluted, cuprous solution is integrated into thin films of indium selenide. The latter are produced using co-evaporation. The amount of copper in the precursor layer obtained by means of the ion exchange reaction is strongly dependant on the substrate. Structure and composition of the layers thus made were determined by means of surface analysis methods. Up to now, the CIGS solar cells manufactured on this basis have achieved efficiencies of 4.1%. The molybdenum back-contact of the cell has, however, been seen to be unstable in the ion-exchange reaction.

The EU's **LARCIS** project [11] is concerned with large-area processes for the industrial production of CIGS solar cells. Here, the Thin Film Physics Group at the ETHZ is concentrating on the optimisation of cell back-contacts on the basis of molybdenum as well as using alternative materials, in particular TiN and ZrN and their combinations with molybdenum. Both for back-contacts making use of TiN and for ZrN in combination with molybdenum, higher values for cell voltage V_{oc}, fill-factor FF and, therefore, higher efficiencies are achieved than without molybdenum. The best efficiencies of 13.9% for ZrN and 13.8% for TiN are obtained with a 10 nm thick molybdenum layer under application of sodium treatment. Various forms of sodium treatment were examined.

In the integrated EU ***ATHLET*** project [12], the Thin Film Physics Group is involved in two work packages on CIGS solar cells. On the one hand, supplementary development work on flexible solar cells on polyimide is in the foreground; on the other hand, new processes for buffer layers on the basis of In_2S_3 and the deposition of solar cells on TCO layers are being examined more intensively. Further work is concerned with the up-scaling onto larger surfaces and the development of tandem solar cells. The best CIGS solar cell was obtained using a 60 nm thick In_2S_3 buffer layer and achieved an efficiency of 14.1%

In a new ***Development of flexible CIGS solar modules with metal grids*** project [13], supported by the Axpo Natural Power Fund, the start-up company *FLISOM* is developing methods for the interconnection of CIGS solar cells on flexible substrates using metallic grids. Various procedures for the interconnection are being examined.

d) Dye-sensitised and organic solar cells

At the ISIC at the EPFL, the development of dye-sensitised, **nano-crystalline solar cells** [14] was pursued further. In the year under review, dye synthesis and long-term stability at higher temperatures (approx. 80°C) of the electrolytes used were foreground activities. Here, a service life of 10 to 20 years for the dye cells is being striven for. Using electrolytes based on ionic liquids, the ISIC, after previously disappointing results, was able to achieve a photovoltaic efficiency of 7.6% in the year under review, which represents a record for solvent-free dye-sensitised solar cells. With a new approach that makes use of eutectic mixtures of fluid salts as a redox electrolyte, an efficiency of 8.2% was achieved. Moreover, first tandem cells featuring a combination with CIGS solar cells were manufactured and achieved an efficiency of 15%.

The new CCEM project ***ThinPV*** [15, 16] co-ordinated by the EMPA in Duebendorf and also supported by *swisselectric research,* brings the different actors in the Swiss thin film solar cell research area together in a single project. In a co-operation between the ISIC at the EPFL and the EMPA in Duebendorf, a new dye was synthesised that makes use of unsymmetrical squaraine dyes. In spite of the narrow spectral bandwidth of this dye, a high rate of yield was achieved with it corresponding to a photovoltaic efficiency of 4.5%. Basic work is also being done on organic solar cells at the EMPA Duebendorf in the laboratory for functional polymers. The emphasis is being placed on the use of cyanine dyes as well as the nano-structuring of the crossover between donor and acceptor materials. In the year under review, it was shown that doping the cyanine dye can lead to a strong increase in photocurrent and, therefore, of the efficiency too. Using doping in a solar cell made of a combination of cyanine and C_{60}-Fullerenes, the efficiency was increased from 0.14% to 1.2%. Further, EMPA Duebendorf is carrying out a CTI feasibility study on the topic of ***Transparent and Flexible Solar Cell Electrodes made from Precision Fabric*** [17].

Solaronix is still involved in the **FULLSPECTRUM** EU project [18], an *Integrated Project* in the area of photovoltaics, which brings together different approaches for the better utilisation of the solar radiation spectrum in one project (III-V multi-junctions, thermophotovoltaics, intermediate band cells, molecular approaches). It is hoped that efficiencies of up to 40 % will be achieved. In this project, Solaronix is especially involved in supporting work in the module on new molecular approaches. This involves the role of solar dye cells in 2-photon processes and flat concentrators. *Solaronix* is concerned here with the measurements of the voltage-current characteristic, spectral sensitivity and the stability of the flat concentrators.

The new EU project ***OrgaPvNet*** [19] is a network project which brings European stakeholders in the field of organic solar cells together and is to develop future strategies in this area. *Solaronix* is one of the 4 SME's involved in this project which involves a total of 22 partners. Project activities up to now have been concentrated on various workshops in which organic solar cells have been the central theme both from the scientific-technical as well as from the market-related points of view.

The EU's ***Napolyde*** [20] project stands for interdisciplinary research activities in the field of nano-structured polymeric deposition with regard to applications in the energy area and in smart devices. It unites 23 different partners from very different areas of special activity and fields of application such as microelectronics, coatings and biomedicine and pursues work on both small and large-area applications. In Switzerland, *Solaronix* and the *CSEM* are involved in this work and photovoltaics is a field being explicitly looked at. Monolithically connected dye cells were produced as small modules (10 x 10 cm^2) with an efficiency of 5.6%.

The Institute for Solar Technology SPF at the University of Applied Sciences in Rapperswil HSR is, together with the SFOE's ***PECNet*** [21] project, creating a competence centre for the solar splitting of water by means of hybrid PV-PEC cells. Primarily, the project is technologically set in the photo-electrochemistry area but, however, also has a possible reference to photovoltaics. In a first step, the various competencies and know-how available have been integrated and relevant publications have been noted. Together with the Energy Centre, the *PEChouse* is being built up as a co-ordination centre at the ISIC of the EPFL.

SOLAR MODULES AND BUILDING INTEGRATION

Building integrated installations still represent the area of photovoltaics receiving primary attention in Switzerland. In this case, it must be stated more precisely, however, what exactly is meant by *building integrated* installations (built-on or built-in - genuine integration). Whilst in recent years low-cost solutions for flat roof applications have often been favoured by solar and eco-power exchanges, further work is being done on the reduction of costs for solutions with a stronger integration aspect. Since in the meanwhile a series of systems have been successfully developed for mounting modules on

buildings (see P+D section also), work is now increasingly being concentrated on the development of the solar modules themselves.

Swiss Solar Systems (3S) has been involved in the EU's ***BIPV-CIS*** project [22] that was concluded in the year under review. The aim of the project was to improve the quality of the integration of photovoltaics in buildings by using thin-film solar cells. As a result of the rapid growth in the photovoltaics market, this aim of the EU project was not fulfilled to the degree initially called for. For *3S,* the aim is to support the integration of photovoltaics into the building shell. For this purpose, suitable products such as photovoltaic roof elements and insulated photovoltaic glazing elements with the necessary electrical connections and cabling are to be developed . Within the framework of the project, a market overview of popular photovoltaics systems was also produced along with a survey of European building standards relevant to photovoltaics. *3S* developed a new roofing element for the building-integration of photovoltaics. This is based on a traditional photovoltaics laminate from which a ready-to-use roof element is manufactured in one step using injection moulding. The concept is fully developed, manufacturing drawings are at an advanced stage and the most important subcontractors are being evaluated, which involves extensive materials testing. In spite of the work being wound up as an EU project, it is intended that work should be further pursued in Switzerland.

A few new concepts and products for the integration of photovoltaics in buildings were tried out within the P+D project framework (see corresponding chapter).

ELECTRICAL SYSTEMS TECHNOLOGY

Generally, the **main emphasis in systems technology** continues to lie on quality assurance aspects of components (modules, inverters), systems (design, energy yield) and installations (long-term monitoring). Particularly in the current phase of rapid market growth, the experience gained from these application-related studies is vital to ensure the safety, reliability and energy-yield of future installations as well as the standardisation of products. Together with continuing cost reductions in the components and systems area, the necessary competitiveness of photovoltaics in installations with a long service life can be achieved in the middle and long-term. Quality assurance is becoming more and more important, as products of inadequate quality have appeared on the market recently [64].

The ISAAC at SUPSI concluded the ***Centrale LEEE-TISO 2003-2006*** project [23] in the year under review. The laboratory, with its class A solar simulator certified for measurements in accordance with ISO 17025 received official accreditation once more in April 2007. The measurements of the current-voltage characteristic of solar modules carried out as a service for third parties clearly increased its work volume; 342 measurements were carried out. Moreover, for particular products, further parameters were determined such as temperature coefficients or the behaviour for differing amounts of insolation.

The 10th test series of outdoor measurements on 14 commercial modules was completed in the year under review (8 mc-Si, 2 sc-Si, 1 HIT, 2 a-Si, 1 CdTe). After 15 months of measuring time, the stabilised power of all modules lay on average at 3.7% below the nominal power i.e. between -0.7% and -8.2% and, therefore, within the product guarantees for all modules. Almost all of the crystalline silicon modules measured during the last 5 test cycles have, on average, shown a small initial degradation of -1.1% in the first hours of operation. The differences in the annual energy production of the 14 module types measured in [kWh/kWp] with their nominal power as a reference averaged 10%; if one takes the actual power measured as a reference, the differences are lower (Fig. 3). In the year under review, the ISAAC continued its work on building-integrated photovoltaics. A product database was compiled, which can be found under www.bipv.ch. (Fig. 4)

The ISAAC was involved in work for the EU ***PERFORMANCE*** project [24]. in the year under review. This 4-year *Integrated Project* co-ordinated by the Fraunhofer Institute for Solar Energy Systems in Freiburg, Germany, is concerned with all pre-normative work from solar cells through to complete systems and from short-term measurements through to long-term analyses. The ISAAC is involved in the research on the performance and energy production of photovoltaic modules as well as in modelling. 6 European test laboratories with differing infrastructures carried out a Round Robin test on crystalline silicon modules in the year under review. The maximum powers measured at the different laboratories are within ±2% of each other. Further such tests are planned; on the one hand for the improvement of procedures and, on the other hand, for different values of insolation. The aim is to ensure that the measured values of all laboratories are within ±1% of each other. The measurements are also to be carried out for thin-film solar modules; this represents a greater challenge to the measurement methods. A Round Robin test for the modelling and prediction of the energy production of the solar modules provided values within ±5% for all technologies and ±3% for crystalline modules.

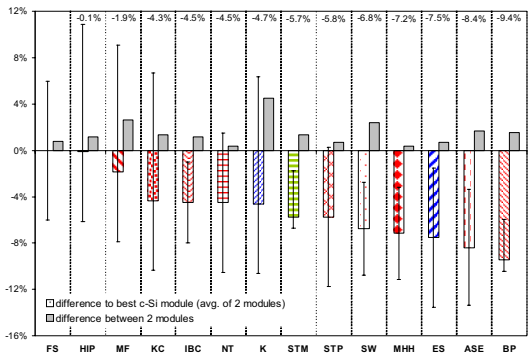

Figure 3: *Differences in the annual energy production of 14 solar modules in [kWh/kWp] (Illustration: ISAAC)*

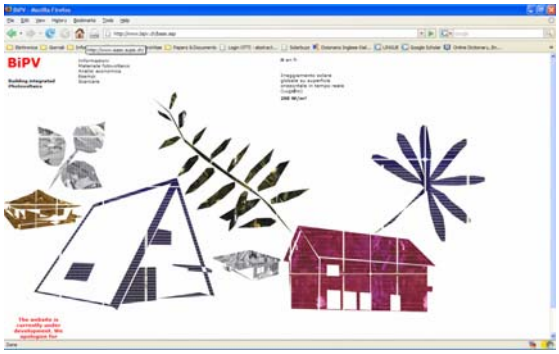

Figure 4: *BIPV home page www.bipv.ch (Illustration: ISAAC)*

The ***efficiency and annual energy production*** of photovoltaic modules were also examined in a PSI project [25] that was concluded in the year under review. On the basis of measurements made on various commercially available modules under various operating conditions, a semi-empirical model for efficiency was parameterised. The model was validated using crystalline silicon modules. Measurements on thin-film modules were also made. In this way, characteristics for the efficiency of the modules were determined as a function of insolation, temperature and air mass. Statements could be made concerning the expected energy production under various climatic conditions.

At the photovoltaics laboratory at the University of Applied Sciences in Burgdorf the ***Photovoltaics System Engineering PVSYSTE*** project [26] was continued. Long-term measurements partly made continuously since 1992 on more than 60 PV installations were continued. The second phase of the installation on the ″Stade de Suisse″ stadium (now 1,35 MW_P) was integrated into the test programme. Once more, the on-going evaluation of fault statistics for inverters showed a pleasingly low number of registered failures in the last year. For the testing of solar inverters, the photovoltaics laboratory of the BFH-TI has, apart from the 60 kWp test installation on the roof, two highly stable, computer-controlled solar generator simulators with powers of 20 kW and 25 kW that can at any time simulate any variable solar generator characteristic desired. The test infrastructure available is not sufficient, however, for the testing of larger centralised inverters that often have a rated output of around 100 kW. In order to be able to make measurements on such modern inverters at full power, the construction of a new solar generator simulator with a rated output of 100 kW was begun (Fig. 5). Up to now, partial current sources (15 sources at 10 A and one source at 5 A) have been built and tested (Fig. 6). The photovoltaics laboratory is also increasingly carrying out measurements on inverters as a service for third parties.

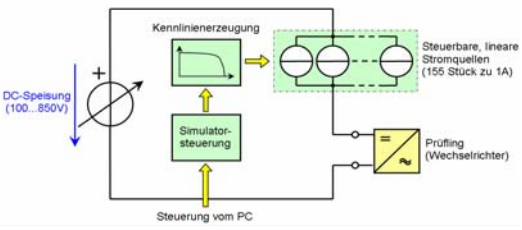

Figure 5: *Block diagram of the 100kW simulator (Illustration BFH-TI)*

Figure 6: *State of completion of the 100 kW simulator in December 2007 (illustration: BFH-TI)*

In the year under review, *Enecolo concluded the* ***SIMIBU*** *project* that has studied the feasibility of an inverter with integrated backup [27]. The aim of the project was to examine the combination of an inverter and a non-interruptible power supply (NIPS). (Fig. 7) As long as the public electricity mains are available, the inverter functions as a normal solar inverter and the NIPS installation is on standby. Only during a mains failure does the NIPS function come into play. The same inverter then supplies the devices connected with power until public mains power returns. In co-operation with *Sputnik Engineering,* the technical feasibility of the concept was demonstrated with justifiable expenditure. Possible fields of use are areas with frequent power breaks, developing countries without mains power but with an option of being provided with mains power later, as well as areas with high mains load during daytime and appropriately expensive peak load tariffs. A pilot installation is now to demonstrate the practicability of the concept.

Independently of this, a similar goal is being pursued by the EU's ***SOS PVI*** *(Security of Supply Photovoltaic Inverter)* project [28] in which *Maxwell Technologies* is co-operating as a Swiss partner. In this project, five prototypes of a corresponding inverter are being developed. Apart from the technical concept for the inverted rectifier, questions on the load curve in specific electricity grids and the necessary control systems are, above all, being examined. (Fig. 8)

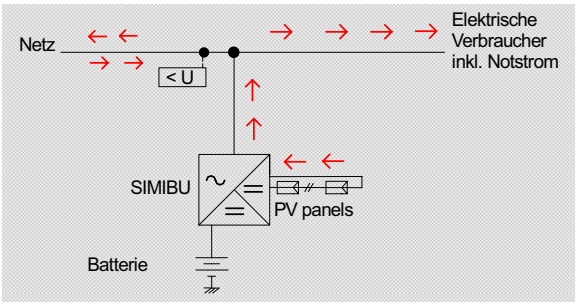

Figure 7: *Current flows in a mains-coupled system with backup function (illustration: Enecolo)*

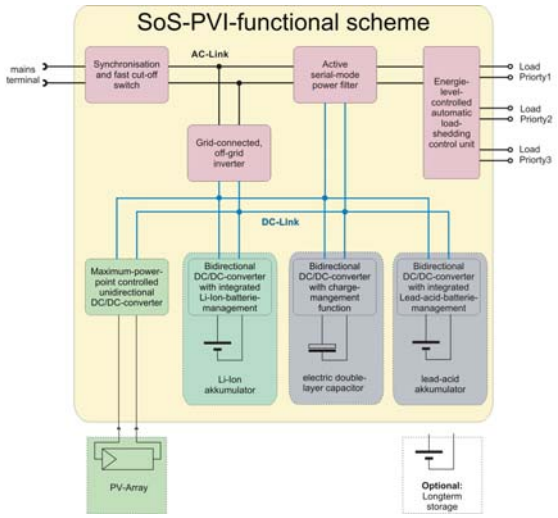

Figure 8: *Architecture of the SOS PVI project (illustration: Maxwell Technologies)*

SUPPLEMENTARY PROJECTS AND STUDIES

Enecolo carried out the ***PV-BUK*** project [29] in the year under review. The aim of this project was to establish the actual operating and maintenance costs (O&M costs) of photovoltaic plant, to estimate the future development of the O&M costs and to develop a list of measures to be taken for the reduction of O&M costs. For this purpose, as much information as possible on the O&M costs was collected from literature as well as by interviews with owners of PV installations in Switzerland and Germany and from experts with the aid of questionnaires. It was found that the operating costs per kWh solar yield sink with increasing system size and increasing specific yield. For a 10 kWp installation the operating costs are approx. 10 Rp./kWh, with a 30 kWp plant 8 Rp./kWh and for a 100 kWp installation 6 Rp./kWh. The largest part of the O&M costs is caused by replacement parts - in particular for inverters.

ESU Services concluded its project ***Update Photovoltaics Ecoinvent Data V2.0*** in the year under review [30]. On the basis of life-cycle inventories of photovoltaics products, new life-cycle analyses (*LCA*) for current industrial photovoltaics technologies were made. In this way, the goal was pursued of publishing environmental analyses of the photovoltaics industry in the Ecoinvent database [65] that are as up-to-date as possible. In addition to the updating of data on mono-crystalline and multi-crystalline solar modules, data on the production and operation of thin-film modules (CIS and CdTe) were collected for the first time. A demonstrative representation of energy payback time is shown in Fig. 9. In this project, it could also be shown to which scale the cumulated energy expenditure for photovoltaics has been reduced in the last 15 years (Fig. 10). The project was carried out in co-operation with the European Photovoltaics Industry Association EPIA and is also a contribution to a corresponding new IEA-PVPS project [31].

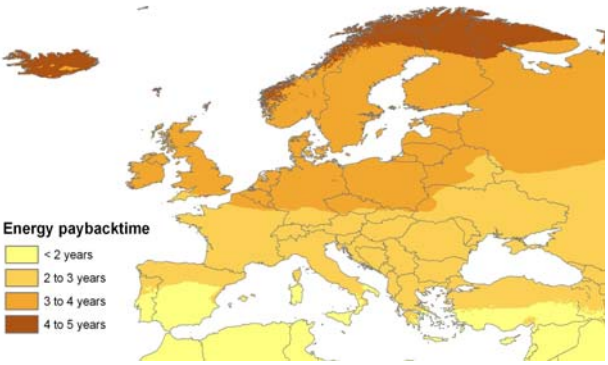

Figure 9: *Energy payback time of a 3 kW multi-crystalline sloping-roof installation in Europe (basis UCTE Mix) (Illustration: ESU Services)*

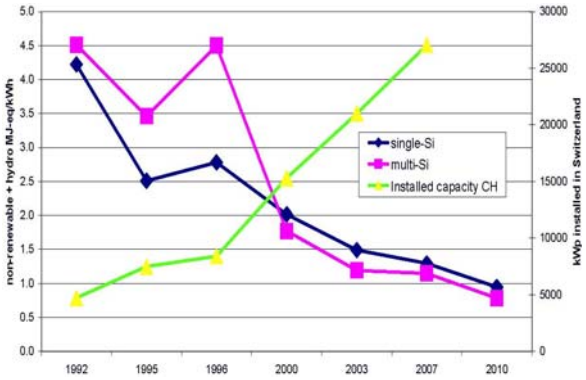

Figure 10: *Cumulative energy expenditure for photovoltaics over time (Illustration: ESU Services)*

The European Space Agency's (ESA) ***ENVISOLAR*** project [32], in which *Enecolo* participated, was concluded in the year under review. The project was aimed at increasing the use of satellite-supported solar radiation data in the solar industry. Using the services developed in the project, site analyses and decisions on locations are simplified, automatic plant-monitoring can be realised and forecasts of the energy production of solar installations can be made. The project's publication provides a excellent overview of the various procedures that exist [66]. In Switzerland, there exists a close relationship to the on-line Photovoltaics Monitoring Service SPYCE [67] that *Enecolo* operates together with *M*eteotest.

The feasibility study on the definition of the potential of ***Quantum Dot Concentrators*** [33] for photovoltaics was concluded by the LESO at the EPFL. Using models and experiments, it was examined whether large-area (laterally acting) concentrators can be realised on glass using this new method, and, also, which electrical power can be provided by it. The Sol-Gel method was used as a technology for the production of the *Quantum Dot* layers. Initial estimates indicate that a system-efficiency of more than 6% can be expected.

With regard to the building integration of photovoltaics becoming more and more important, *Zagsolar*, together with the BRENET network, has developed a ***Concept for a Centre of Competence for Building-integrated Solar Installations*** (photovoltaics and thermal applications) [34]. Here, quality assurance and certification possibilities for products are in the foreground, accompanied by measures for improving information, further education and training.

The PSI is participating in international work on the topic of thermo-photovoltaics (TPV), on the basis of the **FULLSPECTRUM** [35] *EU Integrated Project*. Based on previous projects, in the thermo-photovoltaics module of this project, the PSI is developing system technology aspects in a gas-powered test system. The experimental prototype constructed includes an IR filter, emitter, connections between cells, cell cooling and a system for recording the data obtained. Silicon solar cells are used at the PSI, whereas other institutes are continuing to develop GaSb solar cells.

The highly symbolic **SOLARIMPULSE** project [36] of Bertrand Piccard and various partners continued during the reporting year. The aim of this project is an around-the-world flight with an aircraft powered by photovoltaics. A further project of the visionary kind is the **PlanetSolar** project [37], which is being developed by a group in western Switzerland led by its initiator Raphaël Domjan. PlanetSolar will be a solar-powered boat, which is to round the world on water. Both projects represent primarily private initiatives, whereby co-operation with universities occurs with respect to particular technology-oriented questions. In this way, ***SOLARIMPULSE*** is involved in the CTI project ***Ultralight Photovoltaic Structures*** [38] in which new, ultra-light structures with integrated photovoltaics are being developed together with the EPFL.

Both projects include immense technical challenges, but also enjoy a high level of interest in the general public on account of their potential for communication. Last but not least, the two projects can be seen as being in a certain competition with each other. Along this line of thought, the ***Solar Taxi*** project [39] can also be mentioned, which has made another more concrete step, in that a round-the-world journey with a solar vehicle was begun in Lucerne in summer in 2007. In the meantime, the solar taxi has already reached Australia.

INTERNATIONAL CO-OPERATION WITHIN IEA, IEC, EU

During the reporting period, participation in the IEA Photovoltaics Programme (IEA PVPS) was characterised by continuity both at the project level and in the executive committee (ExCo) [68]. Switzerland continues to chair this world-wide programme. For participation in selected projects within the framework of the IEA PVPS programme, the Swiss IEA PVPS Pool created in 2005 continued its work. This pool is at present supported by the electricity utility of the City of Zurich (ewz), the cantons Basel City and Geneva, the *Mont Soleil Society* as well as by the SWISSOLAR professional association. With this approach, a stronger participation of various target audiences in the work within the framework of IEA PVPS is guaranteed.

Nova Energie represents Switzerland in Task 1 of IEA PVPS which has the task of providing general ***Information Activities*** [40]. In the year under review, a further national report on Photovoltaics in Switzerland up to 2006 [69] was published; on the basis of which the 12th edition of the annual international report on market trends in photovoltaics *("Trends Report"*) in IEA countries was published [70]. This report has become an increasingly quoted reference and was once more used for the current analysis of photovoltaics by the finance sector [71]. Several workshops were organised in the year under review: At the 22nd European Photovoltaics Conference in Milan a workshop took place on the procurement of market data and its interpretation. A further workshop was organised at the Asian conference on Photovoltaics held at the end of 2007 in Fukuoka [72]; which was organised by Switzerland and Japan. The *IEA PVPS Newsletter* [73] regularly informs on work in and around the IEA PVPS programme and is distributed to 250 addressees in Switzerland. In the year under review the IEA PVPS website was reworked [74].

TNC provided the Swiss contribution to IEA PVPS Task 2 on ***Operational Experience*** [41]. This project was concluded in the year under review. The PVPS ***performance database***, that is also available online [75], contains data on photovoltaics installations in 22 countries representing a total of around 1600 years of operation and 13.5 MWp of power production. 66 Swiss plants with a total power of 2 MWp are contained in the database. In the *Photovoltaic System Cost over Time* sub-project, a broadly supported information and database system on the development of PV system prices and maintenance costs was set up. In winding up IEA PVPS Task 2, various papers were published [76, 77, 78, 79]. On account of the importance of quality assurance and reliability for the growing market for photovoltaics installations, it is intended to define a follow-up project for Task 2

Within the framework of the inter-departemental platform (SECO, SDC, FOEN, SFOE) for the promotion of renewable forms of energy in international co-operation *REPIC* [80], *entec* is responsible for the Swiss contribution to IEA PVPS Task 9 on ***photovoltaic services for developing countries*** [42]. Switzerland is responsible for co-ordination of work with bilateral and multilateral organisations. In the year under review, meetings in Germany, France and Belgium were organised within the framework of this project. In its work, Task 9 sets an emphasis on energy services in various fields of application and often occupies itself with approaches which are not limited to photovoltaics alone. During the year under review, the topic of water supply was looked at in particular; Switzerland and Germany organised a workshop in Thailand which examined and openly discussed previous experience gained. Generally, the better networking of important activities in the water supply area is being striven for.

Planair represents Switzerland in IEA PVPS Task 10 on ***Photovoltaics in the Urban Environment*** [43]. From the Swiss point of view, questions on urban planning and on the electricity grid stand in the foreground. Through the inclusion of the City of Neuchâtel in the Swiss contribution, questions pending are to be looked at from the urban perspective in a precise way. Task 10 is in close contact with the EU's ***PV-Upscale*** project [81] which pursues similar goals at a European level***.*** Two transdisciplinay workshops (one in Neuchâtel and one in Zurich) were held in which questions on the status of photovoltaics in urban planning in Switzerland were discussed. Task 10 has published various new reports [82, 83, 84] in the year under review. Here, in particular, the systematic analysis of the added value of photovoltaics in addition to its energy aspect is to be mentioned, which, for the first time, makes differentiated, quantitative and country-specific statements on this subject.

Sputnik represents Switzerland in the IEA PVPS Task 11 ***Hybrid Photovoltaic Systems in Mini-Grids*** [44], an area which - even if not so much in Switzerland - is of increasingly greater interest globally and which addresses comprehensive technical questions on system design, control and the penetration of photovoltaics in the mini-grid area.

ESU Services represents Switzerland in the newly created IEA PVPS Task 12 on the ***Environmental, Safety and Health Issues*** of photovoltaics [31]. The aim of the project is to process and publish relevant and internationally co-ordinated information on this important subject that is as industrially up-to-date as possible. In this way, certain statements that are still partly inconsistent or quantitatively

differing, are to be put on a better basis. In addition, Task 12 is also concerning itself with the recycling of photovoltaic modules.

Meteotest [45] and the CUEPE at the University of Geneva [46] together produce the Swiss contribution to Task 36 ***Solar Resource Knowledge Management*** of the IEA SHC programme. The purpose of this project is to rework the different methods and basic data on solar irradiation as a whole and to make them readily available. Task 36 is part of the IEA SHC programme, but its contents are relevant for all solar technologies; therefore, there is co-operation with the other IEA programmes on solar energy (IEA PVPS and IEA PACES). In this project, the quality of different radiation models and products derived from them are compared and optimised. In the year under review, work was concentrated on irradiation forecasts and the turbidity of the atmosphere.

SWISSOLAR represents Switzerland in the IEC's TC 82 on ***Photovoltaic Standards*** [47]. The work on standards in the area of photovoltaic systems is divided into 6 Working Groups (Glossary, Modules, Non-concentrating Systems, PV Energy Storage, Balance-of-System Components, Concentrator Modules). In every area of technology, standards are an essential component in product design, testing and in quality inspection. The rapidly-developing photovoltaics industry needs a whole range of important, internationally recognised standards, whereby the gap is now starting to be quickly filled thanks to increasing interest in standards. In spite of the IEC's efforts, it could not be prevented that, many national standards in the area of photovoltaics have been developed. These were mostly initiated and in part also financed within the framework of national energy programmes. In recent years interest and the will to harmonise these national standards within the framework of the international IEC have increased. Here, one must distinguish between rules that concern performance and such ones concerning the safety or the quality of the components and installations as well as those concerning the user. Questions on safety are traditionally looked at on a national basis and, up to now, other standardisation committees - with a few exceptions - have not been able to introduce an IEC norm in the area of safety as an obligatory national standard. An exception to this is the EU which introduced parallel voting on IEC and Cenelec standards some years ago. At the moment, 28 documents are being currently being processed by the IEC. In Switzerland, the work is being accompanied by TK 82 [85].

Participation in the EU's **PV-ERA-NET** project [48], which brings together the programme coordination offices and the ministries of 13 countries responsible under the ERA-NET scheme [86], was ensured by the Photovoltaics Programme management (SFOE, *NET Nowak Energie & Technologie*). In this project, Switzerland manages the main part of the work concerning the exchange of information on European photovoltaic programmes. Apart from continuing intercommunication and the maintenance of a project database, models for co-operation between various national programmes were concluded in the year under review. *POLYMOL,* a first joint call for bids covering the subjects of organic and polymer solar cells was made and attracted a total of 9 project propositions. Switzerland is involved in this call for offers. The projects that will be supported are to be selected in the first half of 2008. Another important topic was the *Strategic Research Agenda* (SRA) [63] published by the European Photovoltaics Technology Platform that is considered to be an important European reference document. This document is of importance on account of its comprehensive description of short-term, mid-term and long-term research topics in the photovoltaics area, development time-scales for technology and economic efficiency as well as with respect to the relationships between private and public (national and EU) research.

3. National co-operation

At the national level, the diversity of co-operative effort within the various projects was kept up over the reporting period. Involved in this were the Federal Institutes of Technology, Cantonal Universities, the Universities of Applied Science, research institutes and private industry. Co-operation with industrial companies was especially intensified, both in new projects with the CTI as well as in the form of direct industry mandates for selected research institutes. In the light of a globally growing market for photovoltaics, increasing interest on the part of new industrial companies was noted.

At programme level, co-operation was maintained with numerous federal agencies, cantons and the electricity industry. In this connection, the constant exchange of ideas with SER, CTI, FOEN, SDC and SECO as well as with the electricity sector, the Swiss Electricity Supply Association SESA, *swisselectric* and the *Mont Soleil Association* is worthy of special mention. The large number of contacts made in this way helped to provide a broader base for the programme's activities.

4. International co-operation

International co-operation continued over the reporting period in its many traditional ways. The institutional co-operation taking place within IEA, IEC and the European network projects has already been mentioned. At the project level, co-operation within the EU on new and existing projects continued. In 2007 there were 11 projects in the 6th Framework Research Programmes of the EU, of which 3 are *Integrated Projects* (FULLSPECTRUM, PV-ATHLET, PERFORMANCE). A further project was carried out together with the ESA. Regular contacts occurs with those responsible for programmes in EU countries, as also with those departments responsible in the European Commission.

Switzerland is represented in the European Photovoltaics Technology Platform [87] both in the steering committee as well as in individual working groups. Technology platforms are a new instrument, and are to allow wider sponsoring for selected technologies and a common strategy for those involved. Typically, the research community, industry, the financial sector and government offices are brought together in a commonly supported platform. Work on the R&D efforts necessary as well as on implementation measures is carried out in a co-ordinated manner. Here, the integration of industry, which has an important role to play within the framework of the technology platforms, is of particular importance. In the year under review, the Strategic Research Agenda for Photovoltaic Solar Energy Technology (SRA) [63] was published. Within the framework of the Strategic Energy Technology Plan (SET Plan) [88] proposed by the European Commission, proposals made by the photovoltaic sector on the acceleration of measures to be taken in connection with the EU's energy goals for 2030 were formulated.

Further contacts were maintained with the international organisations concerned with development co-operation (World Bank, GEF, IFC, UNDP, GTZ, KfW, REEEP, etc.). Thanks to these numerous interactions, Swiss photovoltaics has remained very prominent on the international scene.

5. Pilot and demonstration projects (P+D)

As in the previous year, two new SFOE PV P+D projects were also begun this year. In this way, a total of 4 new projects have been initialised since 2003. A further P+D project is supported by the Axpo Natural Power Fund. This is nothing in comparison with the period before 2003, where 10 and more projects were taken up in the P+D programme every year. Fortunately, some of these 'old' projects still set accents in the current photovoltaics market even after several years. The photovoltaics P+D Programme has, in the meantime, shrunk to just a few projects that are mostly in their closing phases. This development is to be regretted very much, as with it an essential link in the transfer of research and development work to industrial production and methods and, therefore, to the market in general has been weakened to a great degree. This means that the effect of this part of the programme remains limited and Swiss companies encounter greater difficulty in bringing new and innovative products in the field of photovoltaics applications onto the market.

In one of the two new SFOE PV P+D projects, the degradation and annealing behaviour of modules with amorphous cells is being examined in more detail on the basis of the successfully concluded P+D project concerning "flat roof integration CPT with thin-film cell modules" [49]. The other project is examining the behaviour of a backup inverter (mains-coupled inverter with interrupt-free power supply USV) in connection with the SIMIBU research project [27] in a practice test.

The photovoltaics P+D projects still running mainly continue to handle the subject of the **Inegration of Photovoltaics in Buildings**

NEW P+D PROJECTS

- Practical testing of a backup inverter (mains-coupled inverter with interrupt-free power supply during blackouts in a practice test; Management: *Enecolo*) [50]
- Degradation and annealing behaviour of modules with amorphous cells (measurements and analysis on the basis of flat roof integration CPT Solar; Management: *ISAAC*) [51]
- 2 kWp Flexcell® experimental roof with flexible amorphous solar cells integrated in a thermoplastic roofing element; Management: *VHF technologies*) [52] (Fig. 11)

CURRENT P+D PROJECTS

In the case of current projects, the zero-energy Ekkharthof school building in Kreuzlingen ("Minergie"-building combined with photovoltaics and heat pump) demonstrates the potential of this concept. With more energy production and less energy consumption than expected, this building demonstrated in 2007 that it is a net energy producer [53] (Fig. 12)

Current projects are (in chronological order):

Installations

- Photovoltaic installation in the zero-energy Ekkharthof school building in Kreuzlingen (integration of a PV installation into the energy concept of a zero-energy school building; Management: *Böhni Energie und Umwelt*) [53] (Fig. 12)
- Roof-mounted installation on a gymnasium in Wiesendangen with amorphous thin-film modules (use of BIOSOL XXL roof elements, consisting of UNI-Solar thin-film modules combined with Solrif mounting frames; Management: *Enecolo*) [54] (Fig. 13)
- 12 kWp Solight pilot system (pilot realisation of two different Solight variants; Management: *Energiebuero*) [55] (Fig.14)

Measurement campaigns

- Wittigkofen measurment campaign (detailed measurement and evaluation with data visualisation of an 80 kWp system mounted on a building facade in Wittigkofen; Management: *Ingenieurbuero Hostettler*) [56]

Studies - tools - various projects

- Swiss Photovoltaic Statistics 2006 (Management: *Ingenieurbuero Hostettler*) [57]

Figure 11: *2 kWp Flexcell* experimental roof *(Illustration: VHF-Technologies)*

Figure 12: *Ekkharthof zero-energy school building in Kreuzlingen (Illustration: Böhni Energie und Umwelt)*

Figure 13: *Roof-mounted plant Wiesendangen gymnasium (Illustration: Enecolo)*

Figure 14: *Solight installation in two variants (Illustration: Energiebuero)*

P+D PROJECTS COMPLETED IN 2007

In 2007, the following P+D projects were concluded (in chronological order):

Installations

- Small, autonomous power supplies with photovoltaics and fuel cells (PV island systems with fuel cells as backup for the autonomous supply of power to remote measuring systems in pilot operation; Management: *Muntwyler Energietechnik*) [58]
- 17.6 kWp flat roof installation with thin-film cell modules at the ETHZ (optically discreet flat roof installation with amorphous cells; Management: *BE Netz*) [59]
- New PV facade system for modules with thin-film cells (development of a universal facade system with or without thermal isolation for thin-film cell modules; Management: *Zagsolar / Wyss Aluhit)* [60]

6. Assessment of 2007 work and prospects for 2008

From the global point of view, the year 2007 was a further successful year for photovoltaics. The photovoltaics industry was able to continue its expansion in a market typified by high market dynamics. The bottleneck in the supply of raw silicon for crystalline silicon cells still exists, however. Worldwide investment in new production capacities for solar silicon are, however, being made which should ease the tense situation in the next few years. In spite of this, the trend-reversal towards lower system prices continued in 2007. In parallel with this, an interesting "window of opportunity" exists for thin-film solar cells - i.e. a chance for this new technology - on account of the tense situation. In 2007, numerous new industry projects with a total production capacity of around 3 GWp/year were announced, whereby first GWp units are being discussed As a concrete example of these recent developments, *oerlikon solar* received further large orders for deposition plant for thin-film solar cells using amorphous silicon in the year under review.

Thanks to the political discussions concerning the Swiss Electricity Supply Law and the planned promotion of renewable forms of energy, the topic of photovoltaics also further received a great deal of attention in Switzerland. With the parliamentary legislation passed in 2007, prospects for improvement in the photovoltaics market after many years of disenchantment now exist in that cost-covering remuneration will be introduced from 2009 onwards. Although very limited on the quantitative scale, this measure should lead to increased activity on the Swiss photovoltaics market and therefore also stimulate technological developments.

The situation of Swiss photovoltaics is also to be judged against this background: On account of broad support, research and technology were, considered internationally, also at a high level. Industrial implementation and international orientation are demonstrated by the numerous CTI and EU projects. On the other hand, important disadvantages for the transfer of know-how in our own country exist as a result of the P+D resources no longer available and the market stagnation noted up to now. In spite of these difficult conditions, increasing industrial photovoltaics activity can also be noted in Switzerland. On the basis of surveys, it is estimated that the export volume in the Swiss photovoltaics area for 2007 is at least 500 million Swiss Francs. Together with the home market, the total turnover of the Swiss photovoltaics industry is estimated to be at least 600 million CHF.

The transfer of the results of Swiss photovoltaics research into industrial products is in recent years to be especially seen in the success story to be found in the area of thin-film solar cells, which has been achieved in good agreement with long-standing programme goals. In the year under review, two specific industry projects were announced in which the production of thin-film solar cells in Switzerland on an industrial scale is being planned for the first time: 25 MW *VHF-Technologies (Flexcell)* in Yverdon, 30 MW by *Pramac* in Locarno. The situation concerning building-integrated photovoltaics presents itself as being promising but a little more difficult since this market is both nationally and internationally not yet particularly distinct. This situation could change on account of new general conditions in Switzerland and in certain other countries e.g. France, in the next few years.

The previous efforts made in the Swiss Photovoltaics Programme represent the scientific and technical starting point around which Swiss innovations and products can present themselves in a rapidly growing photovoltaics market. The long-term practical experience in the construction and operation of

numerous photovoltaics installations has led to important findings which have resulted in the high reliability of the installations and a high specific energy production. In this way, the technological prerequisites have been provided that allow Swiss photovoltaics with its scientific and technical know-how and its products to be competitive and successful in the face of international competition.

On the basis of the wide support it enjoys, the Photovoltaics Programme will continue its attempts to preserve its critical mass and thus be able to make a meaningful impression in the market. For this purpose, use should be made of all possible supporting mechanisms and these should be used simultaneously in an optimally co-ordinated manner in order to reach the goals aimed for. The new energy research concept defined by CORE for the period 2008 - 2011 forms the basis for the orientation of research in the photovoltaics area from 2008 onwards [89]. The corresponding detail research concept will be finished by the beginning of 2008 and submitted to the CORE for approval in the following summer. In this way, recent national and international developments will be considered in order to determine the priorities for the next few years. An intensive exchange of ideas with the various players in research and industry is to accompany this process.

The national exchange of information and experience gained continues to be an important topic in Switzerland. In November 2007, the 7th National Photovoltaics Symposium took place in Lucerne and was extremely well attended. The meeting was dedicated in particular to the new Swiss general conditions for photovoltaics, which explains the great interest that was shown in the meeting. The photovoltaics website http://www.photovoltaic.ch contains all essential information as well as reports and, in this way, serves as an important source of information that is continuously kept up-to-date. The Swiss photovoltaics scene was well represented with its contributions at the 22nd European Photovoltaics Conference in Milan in September [89].

7. List of R+D Projects

(AR) Annual Report 2007 available
(FR) Final Report available (see www.energieforschung.ch under the indicated Project number)

Individual annual and final reports can be downloaded from www.photovoltaic.ch
Further information can be downloaded from the internet addresses cited.

[1] C. Ballif, J. Bailat, F.J. Haug, S. Faÿ, R. Tscharner, (ballif@unine.ch), IMT, UNI-Neuchâtel, *Neuchâtel:* ***Thin film silicon solar cells: advanced processing and characterization*** (AR, FR Project 101'191) www.unine.ch/pv.

[2] F.J. Haug, C. Ballif, (franz-josef.haug@unine.ch), IMT, UNI-Neuchâtel, *Neuchâtel:* ***Flexible photovoltaics: next generation high efficiency and low cost thin film silicon modules*** (AR) www.unine.ch/pv.

[3] S. Olibet, C. Ballif, (sara.olibet@unine.ch), IMT, UNI-Neuchâtel, *Neuchâtel:* ***High efficiency thin-film passivated silicon solar cells and modules - THIFIC: Thin film on crystalline Si*** (AR) www.unine.ch/pv.

[4] C. Ballif, F. J. Haug, V. Terrazzoni-Daudrix, (ballif@unine.ch), IMT, UNI-Neuchâtel, *Neuchâtel:* ***FLEXCELLENCE: Roll-to-roll technology for the production of high efficiency low cost thin film silicon photovoltaic modules*** (AR) www.unine.ch/flex/

[5] N. Wyrsch, C. Ballif, (Nicolas.wyrsch@unine.ch), IMT, UNI-Neuchâtel, *Neuchâtel:* ***ATHLET: Advanced Thin Film Technologies for Cost Effective Photovoltaics*** (AR) http://www.hmi.de/projects/athlet/ / www.unine.ch/pv.

[6] A. Bidiville, K. Wasmer, P. M. Nasch, M. Van der Meer, C. Ballif, J. Michler, (kilian.wasmer@empa.ch), Empa, *Thun:* ***SIWIS: Ultra Thin Silicon Wafer Cutting by Multi-Wire Sawing*** (AR) http://www.empathun.ch.

[7] A. Dimitrov, P. Hoffmann, P. Nasch, (anne.dimitrov@hesge.ch), EIG / EPFL, *Genève:* ***SIRE: Silicon recycling from wafering waste to produce reusable photovoltaic feedstock*** (AR).

[8] P. Nasch, S. Schneeberger, (stefan.schneeberger@amat.com), APPLIED MATERIALS SWITZERLAND, *Cheseaux-sur-Lausanne*: ***BITHINK: Bifacial thin industrial multi-crystalline silicon solar cells*** (AR) http://www.hct.ch / http://www.amat.com/.

[9] D. Brémaud, M. Kälin, A. N. Tiwari, (tiwari@phys.ethz.ch), ETH, *Zürich:* ***Large Area flexible CIGS: Flexible CIGS solar cells on large area polymer foils with in-line deposition methods and application of alternative back contacts*** (AR) http://www.tfp.ethz.ch.

[10] A. N. Tiwari, M. Kälin, (tiwari@phys.ethz.ch), ETH, *Zürich:* ***Thin Film CIGS Solar Cells with a Novel Low Cost Process*** (AR) http://www.tfp.ethz.ch.

[11] D. Brémaud, A. N. Tiwari, (tiwari@phys.ethz.ch), ETH, *Zürich:* ***LARCIS: Large-Area CIS Based Thin-Film Solar Modules for Highly Productive Manufacturing*** (AR) http://www.tfp.ethz.ch.

[12] D. Brémaud, R. Verma, S. Bücheler, S. Seyrling, A. N. Tiwari, (tiwari@phys.ethz.ch), ETH, *Zürich:* ***ATHLET: Advanced Thin-Film Technologies for Cost Effective Photovoltaics*** (AR) http://www.hmi.de/projects/athlet/ / http://www.tfp.ethz.ch.

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(AR) Annual Report 2007 available
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Individual annual and final reports can be downloaded from www.photovoltaic.ch
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11. Abbreviations (incl. Internet Links)

General

ETH	Swiss Federal Institute of Technology

National Institutions

BFH-TI	Berne University of Applied Sciences - Engineering and Information Technology	http://www.ti.bfh.ch
CCEM	Competence Center for Energy and Mobility	http://www.ccem.ch

CORE	Swiss Federal Energy Research Commission	http://www.bfe.admin.ch
CRPP	The Plasma Physics Research Centre of Switzerland EPFL	http://crppwww.epfl.ch
CSEM	Swiss Center for Electronics and Microtechnology	http://www.csem.ch
CTI	The Innovation Promotion Agency	http://www.kti-cti.ch
CUEPE	University of Geneva - The Energy Group	http://www.unige.ch/cuepe
DACD SUPSI	Architecture Construction and Design Departement	http://www.dacd.supsi.ch
EMPA	Swiss Federal Laboratories for Materials Testing and Research	http://www.empa.ch
EPFL	Swiss Federal Institute of Technology Lausanne	http://www.epfl.ch
ETHZ	Swiss Federal Institute of Technology Zurich	http://www.ethz.ch
FOEN	Federal Office for the Environment	http://www.bafu.admin.ch
HSR	University of Applied Sciences Rapperswil	http://www.hsr.ch
IEC	International Electrotechnical Commission	http://www.iec.ch/
IMT	Institute of microtechnology University Neuchâtel	http://www2.unine.ch/imt
ISIC	Institute of Chemical Sciences and Engineering EPFL	http://isic.epfl.ch
ISAAC	Institute for applied sustainability to the built environment SUPSI	http://www.isaac.supsi.ch
LESO	Solar Energy and Building Physics Laboratory EPFL	http://leso.epfl.ch
NTB	Interstate University of Applied Sciences of Technology Buchs	http://www.ntb.ch
PSI	Paul Scherer Institute	http://www.psi.ch
SDC	Swiss Agency for Development and Cooperation	http://www.sdc.admin.ch
SER	State Secretariat for Education and Research	http://www.sbf.admin.ch
SESA	Swiss Electricity Supply Association	http://www.strom.ch
SECO	State Secretariat for Economic Affairs	http://www.seco.admin.ch
SFOE	Swiss Federal Office of Energy	http://www.sfoe.admin.ch
SUPSI	The University of Applied Sciences of Southern Switzerland	http://www.supsi.ch

International Organisations

EU (RTD)	European Union (RTD-Programme) Community Research & Development Information Service of the European Communities	http://www.cordis.lu
ESA	European Space Agency	http://www.esa.int
GEF	Global Environment Facility	http://www.gefweb.org
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit	http://www.gtz.de
IEA	International Energy Agency	http://www.iea.org
IEA SHC	IEA Solar Heating and Cooling Programme	http://www.iea-shc.org
IEA PACES	IEA Solar Power and Chemical Energy Systems Programme	http://www.solarpaces.org
IEA PVPS	IEA Photovoltaic Power Systems Programme	http://www.iea-pvps.org
IEC	International Electrotechnical Commission	http://www.iec.ch
IFC	International Finance Corporation	http://www.ifc.org
KfW	Kreditanstalt für Wiederaufbau	http://www.kfw.de
REEEP	Renewable energy & energy efficiency partnership	http://www.reeep.org
UNDP	United Nations Development Programme	http://www.undp.org
UNEP	United Nations Environment Programme	http://www.unep.org

12. Further Internet Links

	Swiss Photovoltaic Website	http://www.photovoltaic.ch
	Programme SwissEnergy	http://www.energie-schweiz.ch
	Swiss Energy Research	http://www.energy-research.ch
SNF	Swiss National Science Foundation	http://www.snf.ch
ETH- Board	Board of the Swiss Federal Institutes of Technology	http://www.ethrat.ch
SFSO	Swiss Federal Statistical Office	http://www.bfs.admin.ch
IGE	Swiss Federal Institute of Intellectual Property	http://www.ige.ch
METAS	Swiss Federal Office of Metrology	http://www.metas.ch
Swissolar	Swiss Professionals Association for Solar Energy	http://www.swissolar.ch
SSES	Swiss Solar Energy Society	http://www.sses.ch
	US Department of Energy, Photovoltaic Program	http://www.eere.energy.gov/solar
ISES	International Solar Energy Society	http://www.ises.org
ESRA	European Solar Radiation Atlas	http://www.helioclim.net/esra

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Confederazione Svizzera
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Office fédéral de l'énergie OFEN

THIN FILM SILICON SOLAR CELLS: ADVANCED PROCESSING AND CHARACTERIZATION

Annual Report 2007

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Project- / Contract Number	101191 / 151399
Duration of the Project (from – to)	01.01.2005 – 31.12.2007
Date	30.11.07

ABSTRACT

This project aims at introducing new ideas and processes for the fabrication of high efficiency thin film silicon solar cells. In 2007, last project year, the major results are the followings:

- Detailed electrical and microstructural investigations have allowed a clearer understanding of the interaction of the substrate and of the films grown by plasma processes (PECVD). In particular, the presence of cracks and defective areas has been analyzed for various solar cells on glass and plastic substrates and their origin is clarified.
- A new material based on doped silicon oxyde has been developed and used as intermediate reflector in various solar cells. This layer can be prepared by PECVD and allows an increase in the current of the amorphous top cell. An initial efficiency of 12.2% for a 1.2 cm^2 micromorph cell has been achieved.
- Progresses have been achieved in the fabrication of amorphous and micro crystalline silicon solar cells on plastic substrates. In particular microcrystalline solar cells with up to 8.6% efficiency on PET/PEN plastic gratings could be obtained.
- A better physical understanding of the opto electronic properties of zinc oxyde prepared by low pressure chemical vapour deposition has been gained. In particular the role of grain boundaries in controlling the mobility has been elucidated and the effect of vapor moisture on the films clarified.

In parallel, a new large area, fully automated, cluster deposition system was taken into operation and should allow faster progresses in the next projects.

Several of the findings of this last project year are relevant for industrial implementation at a later stage and will be worked out in the frame of CTI projects or direct mandates with industrial partners.

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FLEXIBLE PHOTOVOLTAICS: NEXT GENERATION HIGH EFFICIENCY AND LOW COST THIN FILM SILICON MODULES

Annual Report 2007

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Project- / Contract Number	CTI 8809
Duration of the Project (from – to)	01.10.2007 – 30.09.2009
Date	10.12.07

ABSTRACT

The company VHF-Technologies is currently commercialising its "first" generation product, based on the fabrication of amorphous silicon single junction modules prepared on flat plastic foils. Typical stabilised module efficiencies are in the range of 4.5%. The IMT of Neuchâtel has achieved in other projects the fabrication of significantly higher efficiency devices on textured substrates. The objective of this new CTI project, which started recently, is an improvement or development of specific devices in the laboratory, and their successful transfer to production processes, aiming at the development of flexible photovoltaic modules with higher efficiency (gain up to 30-40% relative efficiency). More specifically, we propose the introduction of a new back reflector structure incorporating diffusely scattering surfaces which enhance the light path inside the thin silicon layers, assisted by a dielectric mirror which boosts the reflective properties. In parallel, area losses of the module interconnection will be substantially reduced by the development of a tandem structure based on amorphous silicon (a-Si). The final goal of the project is to demonstrate a process suitable for the fabrication of 6% reliable flexible modules.

Here, we briefly present the first project results. In particular we show that it is possible to fabricate tandem a-Si/a-Si devices with current up to to 7.4 mA/cm^2 on plastic substrates. An initial efficiency of 8.8% is achieved for such solar cells.

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Bundesamt für Energie BFE

HIGH EFFICIENCY THIN-FILM PASSIVATED SILICON SOLAR CELLS AND MODULES

THIFIC: THIN FILM ON CRYSTALLINE SI

Annual Report 2007

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Project- / Contract Number	Axpo Naturstrom-fonds 0703
Duration of the Project (from – to)	01.06.2007-31.05.2011
Date	29.11.2007

ABSTRACT

THIFIC (Thin film on crystalline Si) is a new project sponsored by the Axpo Naturstrom-Fonds. It aims at developing a new kind of ultra-high efficiency (20-22%) solar cells, by depositing very thin film silicon layers (typically 5-10 nanometers of amorphous and/or microcrystalline silicon) on top of silicon wafers. These so-called “silicon heterojunction cells” can be processed at low temperature (typically 200°C) and can make use of thin wafers (down to 100 µm), thereby saving Si material. The cells will be integrated into innovative light weight modules with efficiencies reaching up to 20%. These concepts should open the path towards a really competitive production of solar electricity based on high efficiency crystalline Si products. This wafer based approach is complementary to the fabrication of solar modules based exclusively on thin films, which should allow the fabrication of lower efficiency modules at lower cost/W_p.

At the Institute of Microtechnology of the University of Neuchâtel, an activity was started in 2005 in the field silicon heterojunctions. On small area devices (4.5x4.5mm^2), an open-circuit voltage higher than 700 millivolt and an efficiency of 19% were achieved on flat monocrystalline n-type wafers. This Axpo Naturstrom-Fonds project launch was hence based on the good results achieved in a short time at IMT. Meanwhile, a single process step analysis was elaborated for the better physical understanding of interface phenomena occurring in silicon heterojunction solar cells. This allows a fast heterojunction solar cell development. Textured crystalline silicon – allowing a solar cell current improvement by light trapping – could be cleaned successfully. With further texture based adaptations, we recently achieved an open-circuit voltage of 700 millivolt, also on textured wafers.

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FLEXCELLENCE: ROLL-TO-ROLL TECHNOLOGY FOR THE PRODUCTION OF HIGH EFFICIENCY LOW COST THIN FILM SILICON PHOTOVOLTAIC MODULES

Annual Report 2007

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Project- / Contract Number	SES-CT-019948
Duration of the Project (from – to)	01.10.2005 – 30.09.2008
Date	10.12.2007

ABSTRACT

We report here on all the "mid-term" results obtained in the frame of the European FLEXCELLENCE project (www.unine.ch/flex) coordinated by the University of Neuchâtel. FLEXCELLENCE aims at developing the equipment and the processes for cost-effective roll-to-roll production of high-efficiency thin-film modules, based on amorphous (a-Si:H) and microcrystalline silicon (µc-Si:H). Eight partners, with extended experience in complementary fields ranging from device simulation to machinery development, are involved.

During this first part of the project several milestones were achieved:

- Setting-up and operation of roll–to-roll systems for deposition of solar cells by micro-wave PECVD, Hot-wire and VHF PECVD.
- Fabrication of high quality nanotextured substrates both on plastic foils and on metal foils with insulation.
- Achievement of high efficiency devices on textured plastic substrates with initial efficiencies of 10.9% for tandem micromorph cells.
- Improvement in interconnection technologies, module encapsulation and reliability.
- Demonstration of the possibility to reach ultra-low cost (< 0.6 €/Wp) if high efficiency micromorph concepts can be realised in production.
- Successful integration by one of the partners of new high-throughput VHF-electrodes and move to module mass-production.

Thanks to the collaborative nature of the project, important steps towards the goal of mass-production of high efficiency thin film Si modules have consequently been realised

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ATHLET
ADVANCED THIN FILM TECHNOLOGIES FOR COST EFFECTIVE PHOTOVOLTAICS

Annual Report 2007

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Project- / Contract Number	IP 019670
Duration of the Project (from – to)	01.01.2006 – 31.12.2009
Date	December 2007

ABSTRACT

ATHLET (Advanced Thin Film Technologies for Cost Effective Photovoltaics) is an European integrated project (IP) financed by the 6th framework program. The consortium of 23 partners (and 5 associated partners) from 11 EU countries is led by HMI Berlin. The consortium comprises also 3 Swiss partners: IMT, Oerlikon and the ETH Zurich. ATHLET's main goal is to provide scientific and technological basis for an industrial mass production of cost effective and highly efficient, environmentally sound, large-area thin film solar cells and modules. It focuses thus in the development of thin-film silicon solar cells and modules, as well as chalcopyrites cells and modules with Cd-free buffer. The project aims at providing production and module concept for a price/efficiency ratio of 0.5 €/W_p or lower.

Regarding thin-film silicon, the project target is to developed micromorph tandem > 1 m^2 modules with a stable efficiency of 10% fabricated at a deposition rate of at least 10 Å/s. In parallel, small area cells will be further developed (next generation of cells) in order to reach a stable efficiency of 14%.

Within the second year, IMT work within Athlet was split on the further development of micromorph tandem on small area, on the development of micromorph tandem cell components in an industrial KAI-S reactor and on the set-up of our new double chamber KAI-M reactor (including process transfer and diagnostic tool implementation). The work on small area focused mainly on the improvement of the light management in the micromorph tandem, by introducing anti reflection layers and a new intermediate reflector aiming at 12% stable efficicieny. In the KAI-M system, a-Si:H top cell has been considerably improved and a new deposition regime at lower power for μc-Si:H was explored in order to reduce powder formation and heating of the substrate. Initial efficiencies of ≥10.5% have been obtained for both a-Si:H and micromorph tandem cells.

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SIWIS

ULTRA THIN SILICON WAFER CUTTING BY MULTI-WIRE SAWING

Annual Report 2007

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Project- / Contract Number	CTI Nº 7730.2 NMPP-NM
Duration of the Project (from – to)	01.12.05 – 30.11.07
Date	13.12.2007

ABSTRACT

The objectives of the SIWIS project are to understand and to control the surface defect generation mechanisms governing the yield in multi-wire sawing of silicon wafers. The development activities of the project focus on analysing and characterising surfaces of sawn wafers and to develop models to predict surface damage during free wire sawing. The main motivation behind this project is to develop a multi-wire-sawing process technology that allows mass production of thin crystalline silicon wafer (<100μm) suitable for solar cell production. As of today, the following specific points were achieved:

- Measurement of roughness of sawn wafer to determine the influences of sawing parameters.
- Measurement of sub-surface defects of sawn wafer to determine the effects of sawing parameters.
- Scratching and indentation of silicon by conventional and *in-situ* scanning electron microscope. This study allows a fundamental understanding of the deformation process in silicon.
- Compression tests of micro-pillars under Raman spectroscopy, which allows to explore phase transformations and fracture mechanisms under uniaxial stress
- Development of a bench test for wafer strength measurements
- A correlation between the roughness and the cracks depth was found for varying sawing parameters. The same trend was observed on fracture strength.

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SILICON RECYCLING FROM WAFERING WASTE TO PRODUCE REUSABLE PHOTOVOLTAIC FEEDSTOCK

FEASABILITY STUDY

Annual Report 2007

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Project- / Contract Number	CTI 8829.2 PFIW-IW
Duration of the Project (from – to)	6 months (April 2007 – december 2007)
Date	7 december 2007

ABSTRACT

The objective of the SIRE project was the demonstration of a process that allows the recycling of 80% of the silicon saw residues contained in exhausted wire-saw cutting slurries from the production of silicon wafers for the photovoltaic (PV) industry. During the slicing of silicon blocks into thin wafers (150-200 micron thick) by multi-wire slurry sawing (MWSS) technology, around 50% of the silicon (or about 3 tons of silicon per MW produced PV power at 15% module efficiency), that entered the wafering process, is lost in form of fine, micron sized silicon powders which accumulate in the wire sawing slurries.

The operating conditions in laboratory tests have been developped and it was shown that silicon can be separated from silicon carbide in artificial mixtures as well as in real industrial waste samples. Process for Intellectual Property protection of the invention is ongoing.

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BIFACIAL THIN INDUSTRIAL MULTI-CRYSTALLINE SILICON SOLAR CELLS

BITHINK

Annual Report 2007

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Project- / Contract Number	503105 / BBW 03.0086
Duration of the Project (from – to)	09.2004 - 09.2007
Date	7.12.2007

ABSTRACT

The BiThink objective is to develop and demonstrate an industrial technology able to exert direct influence on the cost of photovoltaic systems. BiThink focuses on three key aspects: the use of bifacial cells and albedo modules as a simple way to increase the amount of energy collected, the increase in the number of wafers obtained from the slicing of silicon ingots and the use of a simple and efficient manufacturing process, able to combine high mechanical yields with reasonable cell efficiency.

Thin slicing of silicon ingots was carried out by HCT using the Multi-Wire Slurry Slicing technique (MWSS). The wafer thicknesses have been decreased from over 250 μm thick at start of project to lower than 100 μm (90μm). Wire diameters have been diminished from 160 μm to 120 μm. The target of the project was to go from the industrial value of 1800 wafers per linear meter of silicon ingot (w/m) towards the range of 3500 – 4000 w/m. Today's achievement is more than 3500 w/m for 156x 156 mm^2 multicrystalline silicon brick. The wafer thickness total variation is in average of 31 μm with standard deviation of 3 μm. The standard deviation for the mean thickness is only of 2 μm. This result means a gain of 88% over technology at the start of the project. Another challenging objective of the project was the singulation (separation of as-cut wafers) of thin wafers with high yield values. An innovative solution has been developed within this project that allows very thin wafers to be separated and handled limiting the stress applied on the wafer, hence reducing breakage rate.

Technology developed in the BiThink project is demonstrating impressive numbers in low consumption of silicon: 3500 wafers can be obtained from a meter of silicon ingot with a 95% yield that means 1.45 m^2 of silicon wafers from a kilogram of silicon. Using the current BSF bifacial technology, with an efficiency of 13%, 100% bifaciality and using the lower albedo factor of 30%, gives a consumption of 3.9 grams/Wp without taking account the yield. Using the 95% of yield for the slicing process and 90% for the solar cell production this number is 4.6 g/Wp. The simple optimization of cell technology to 15% of efficiency with bifaciality of 100% gives to values lower than 4 g/Wp.

BiThink shows impressive figures. Another important result is the large amount of new technology developed in the project in the areas of ingot slicing, post-slicing wafer separation, screen printing diffusion, mechanical handling, crack detection, and thin solar cell interconnection.

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LARGE AREA FLEXIBLE CIGS

Flexible CIGS solar cells on large area polymer foils with in-line deposition methods and application of alternative back contacts

Annual Report 2007

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Project- / Contract Number	100964 / 152404
Duration of the Project (from – to)	01.12.2006 - 28.02.2009
Date	31.01.2008

ABSTRACT

Flexible $Cu(In,Ga)Se_2$, called CIGS, solar cells are important for a variety of terrestrial applications. This project aims at the development of high efficiency flexible CIGS solar cells on large area (up to 30 x 30 cm^2) polyimide foils. All the component layers (Mo by sputtering, CIGS by evaporation, CdS by chemical bath deposition, ZnO/ZnO:Al by sputtering) of the flexible solar cells will be grown on in-line moving substrates. The “home-build” CIGS and customised CdS deposition equipments will be improvised with emphasis on improving the performance, process reproducibility and large area in-line deposition capabilities. A low temperature CIGS deposition process and controlled Na incorporation will be optimised towards developing 12% efficiency flexible solar cells with all in-line processes is still higher than the current state of the art of worldwide competing groups on this topic.

Alternative electrical back contacts to conventional Mo will be developed on flexible polyimide foils. The deposition processes will be optimized for flexible CIGS solar cells on alternative back contacts and their advantages will be evaluated.

The developed evaporators were evaluated in terms of evaporation profiles and layer thickness and composition across the substrate width were analysed. Reasonable homogeneity was obtained over a substrate width of at least 25cm. Further the chemical bath deposition equipment was redesigned for large area substrates and optimized for minimal waste products.

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THIN FILM CIGS SOLAR CELLS WITH A NOVEL LOW COST PROCESS

Annual Report 2007

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Project- / Contract Number	100964 / 152223
Duration of the Project (from – to)	01.11.2006 - 31.10.2008
Date	17.12.2007

ABSTRACT

A novel low-cost process for the production of thin film $Cu(In,Ga)Se_2$ solar cells using an ion exchange reaction in liquid solutions is developed. The process involves the deposition of a In_2Se_3 or $(In,Ga)Se_2$ precursor layer, a step for low temperature in-diffusion of copper atoms and further thermal annealing in selenium containing atmosphere where the precursor is converted to the $Cu(In,Ga)Se_2$ compound. Efficiencies up to 4.1% were obtained in the first phase of the project.

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LARCIS

Large-Area CIS Based Solar Modules for Highly Productive Manufacturing

Annual Report 2007

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Project- / Contract Number	SES66-CT-2005-019757 / FP6-019757
Duration of the Project (from – to)	01.11.2005 – 31.10.2009
Date	31.01.2008

ABSTRACT

This European collaborative project within the FP-6 EU program involves 6 universities and 4 industries working together towards the development of large area Cu(In,Ga)Se_2 (CIGS) based thin film solar modules for highly productive manufacturing. The project will improve the device performance and manufacturing technologies for low-cost, more stable, more efficient solar modules. In this project vacuum evaporation and electrodeposition approaches are used for absorber deposition and other components of the solar cells are improved. Important objectives of the overall project are manufacture of CIGS by co-evaporation, application of cost-effective methods and development of alternative buffer and back contact layers for large are CIGS.

To meet the above mentioned objectives, research and development (R&D) work of the ETH group is directed on the development of alternative back contacts for improvement of efficiency, stability and to explore the possibility of reducing the CIGS absorber layer thickness. Another R&D activity of the ETH group is to modify the CIS absorber in such a way that a separate deposition of the buffer layer could be avoided.

In order to develop alternative (to Mo) electrical back contacts providing multi-functionality we have investigated ZrN as possible candidate because of its physical and chemical properties. A thin layer of $MoSe_2$, which is known to facilitate ohmic transport of carriers between CIGS and back contact, was applied prior to CIGS deposition. The influence of the $MoSe_2$ intermediate layer was investigated. We have successfully developed cells with efficiencies up to almost 14% by using post-deposition Na incorporation method. The achieved efficiencies are comparable to the efficiencies with conventional 1 micron thick Mo layer or on TiN. SIMS measurements were also performed to investigate some inconsistencies observed on TiN and reported in the previous report.

The microstructural behavior and the photovoltaic properties of different Na incorporation methods have also been investigated. The results show that Na influences the grain size of the CIGS layer, if present during growth, but post-deposition incorporation gives better photovoltaic properties for deposition at low substrate temperatures.

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ATHLET

Advanced Thin Film Technologies for Cost Effective Photovoltaics

Annual Report 2007

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Project- / Contract Number	ATHLET CIS / FP-2204-Energy-3
Duration of the Project (from – to)	01.01.2006 – 31.12.2009
Date	20.12.07

ABSTRACT

The ATHLET project is an integrated project of the European Union involving 24 partners consisting of universities, research institutions and industries working on the topic of $Cu(In,Ga)Se_2$ (called CIGS) and Si based thin film solar cells. The project is divided in several work packages covering diverse topics of solar cells and modules. The Thin Film Physics Group (TFP) of ETH Zurich is participating in two work packages within the integrated EU project with the objective to investigate alternative buffer layers deposited by vacuum evaporation or ultrasonic spray pyrolysis and the developement of high efficiency CIGS solar cells on flexible substrates and for tandem solar cells

CIGS solar cells on ITO transparent conducting oxide (TCO) coated glass substrates were developed for their future application in tandem solar cells. We have developed CIGS solar cells with efficiencies up to 13.3%, where both the front and back contacts are TCOs.

Physical vapor deposition (PVD) method was employed to deposit In_2S_3 buffer layers on CIGS absorber with In_2S_3 powder as source material. The microstructural behavior and chemical composition of the source materials as a function of the time of evaporation have been studied. A significant amount of sulfur loss was detected in coarse powder, while the finer powder was found to be chemically stable. X-ray diffraction (XRD) examination revealed the presence of In_2O_3 in the coarse powder after 4 min of evaporation. Solar cells made of a buffer layer deposited from fine powder resulted in lower efficiency (8.6%) than that made from coarse powder (11.6%). A maximum efficiency of 12.1% was reached after air annealing of the completed cell. A highly efficient solar cell of 14.1% efficiency was developed with a ~60 nm thin In_2S_3 buffer layer. At this stage there are problems of reproducibility, especially about the influences of annealing treatments. Further work is necessary to improve the process reliability and to gain understanding of the annealing and light soaking effects.

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DEVELOPMENT OF FLEXIBLE CIGS SOLAR MODULES WITH METAL GRIDS

Annual Report 2007

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Project- / Contract Number	sponsored by axpo Naturstrom Fonds
Duration of the Project (from – to)	Januar 2007 – August 2008
Date	Dezember 2007

ABSTRACT

The project focuses on scaling up CIGS thin film technology on flexible substrates and prototype module development via metal grid interconnection. The project results include flexible modules with various output voltages made of high efficiency absorber materials and based on a concept that resulted in a world record efficiency of 14.1 % for solar cells on plastic foils.

In this project various processing steps for the production of flexible CIGS solar modules with metal grid interconnection will be investigated. This technology should allow the flexible CIGS technology to enter the market sooner. Mini modules for demonstration applications with electronic devices would prove the concept and potential of high efficiency flexible CIGS solar cells. Important conclusions will be drawn from the results for manufacturing and design optimisation.

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DYE-SENSITISED NANOCRYSTALLINE SOLAR CELLS

Annual Report 2007

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Project- / Contract Number	Project EPFL
Duration of the Project (from – to)	January 2007 – December 2007
Date	December 2007

ABSTRACT

Recently the historic trend to lower prices for photovoltaic cells, modules and systems has been reversed. This is a particular challenge to the photovoltaic industry, at a time when general energy prices are also rising and a breakthrough opportunity is presented. The price rise centres on the availability of photovoltaic-quality silicon for the conventional solid state devices. In these circumstances the interest in thin-film devices, including sensitised photoelectrochemical and heterojunction devices, becomes even more intense. Sensitised photoelectrochemical devices are a significant technical and commercial alternative to those conventional solid-state junction photovoltaic devices for solar energy applications. In the standard solid state photovoltaic devices semiconductor layers absorb light and thereby produce electron-hole pairs, which are subsequently separated to provide a photovoltage by junctions, either with other semiconductors or at Schottky contacts with metals. In the photoelectrochemical system the contacting phase is an electrolyte. However standard semiconductors with absorption properties compatible with visible light are in general unstable in contact with electrolytes. Wide bandgap semiconductors are suitable, if sensitised to the visible spectrum by electroactive dyes. In the dye-sensitised system the recombination loss mechanism is minimised since the processes of optical absorption and charge separation take place on distinct phases within these photovoltaic cells. In consequence oppositely charged species are restricted to separate phases. Therefore device photoconversion efficiency is maintained even at low light levels. Recent results on enhanced device stability are particularly significant for future commercial applications.

Sensitised heterojuctions, which are a further option in the development of low-cost thin film photovoltaic deviices, are also under development in this laboratory.

A hybrid variant is also under investigation, the dye-sensitised solid state heterojunction, where the electrolyte phase is replaced by an organic charge transport medium. A further implementation of the dye-sensitised cell is as a component in optical-series tandem cells, for extended spectral matching or for photoelectrolysis.

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EFFICIENT FAR RED SENSITIZATION OF NANOCRYSTALLINE TiO_2 FILMS BY AN UNSYMMETRICAL SQUARAINE DYE

Annual Report 2007

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Project- / Contract Number	CCEM-ThinPV project Part B; Empa
Duration of the Project (from – to)	2007-2009
Date	1.4.2007

ABSTRACT

An asymmetric squaraine sensitizer comprising an anchoring group were engineered at molecular level and synthesized. When used as sensitizer for the nanocrystalline TiO_2 film in standard DSC cells, an unprecedented incident photon to current conversion efficiency of 85% was achieved. A short circuit photocurrent density of 10.5 ± 0.2 mA/cm^2, an open circuit voltage of 603 ± 10 mV and a fill factor of 0.71 ± 0.02 were obtained, corresponding to an overall power conversion efficiency of 4.50 % under standard AM 1.5 sunlight. Interestingly, given the rather narrow spectral bandwidth where the device is photoactive, the achieved power efficiency is remarkable and is the highest one obtained with squaraine dyes so far. The novel sensitizer benefits from an extremely high extinction coefficient, which offers the possibility to use the dye as co-sensitizer.

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DOPING OF CYANINE SOLAR CELLS: ENHANCING CHARGE TRANSPORT

Annual Report 2007

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Project- / Contract Number	CCEM-ThinPV project Part B
Duration of the Project (from – to)	2007-2009
Date	1.4.2007

ABSTRACT

Organic solar cells are currently subject to intense research efforts spurred by the promise of providing low cost devices to the growing photovoltaic market. Cyanine based materials are very strong light absorbers but have yet to prove their suitability for photovoltaics in terms of charge carrier transport. Photoinduced doping by oxygen demonstrates that charge carrier transport can be enhanced importantly in these materials, which may be a loophole to the charge carrier mobility limitation. When used in bilayer thin film photovoltaic devices, doped materials give rise to a ten-fold increase of the power conversion efficiency as compared to the pristine materials.

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FULLSPECTRUM

A NEW PV WAVE MAKING MORE EFFICIENT USE OF THE SOLAR SPECTRUM

Annual Report 2007

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Project- / Contract Number	SES6-CT-2003-502620 / SER N° 03.0111-2
Duration of the Project (from – to)	1.11.2003 – 31.10.2008
Date	05.02.2008

ABSTRACT

FULLSPECTRUM is an EU integrated project whose primary objective is to make use of the FULL solar SPECTRUM to produce electricity. The necessity for this research is easily understood, for example, from the fact that present commercial solar cells used for terrestrial applications are based on single gap semiconductor solar cells. These cells can by no means make use of the energy of below bandgap energy photons, since these simply cannot be absorbed by the material. The achievement of this general objective is pursued through five strategies: a) the development of high efficiency multijunction solar cells based on III-V compounds, b) the development of thermophotovoltaic converters, c) the research on intermediate band solar cells, d) the search of molecules and dyes capable of undergoing two photon processes and e) the development of manufacturing techniques suitable to industrialize the most promising concepts.

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ORGAPVNET

Coordination Action towards stable and low-cost organic solar cell technologies and their application

Annual Report 2007

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Project- / Contract Number	SES6-038889
Duration of the Project (from – to)	01.11.2006 – 30.04.2009
Date	05.02.2008

ABSTRACT

One can observe a strongly increasing R&D-effort in the domain of solar cells based on organic layers. This progress is essentially based on the introduction of nanostructured material systems to enhance the photovoltaic performance of these devices. The growing interest is fuelled by the potentially very low cost of organic solar cells thanks to the low cost of the involved substrates, the low cost of the active materials of the solar cell, the low energy input for the actual solar cell/module process and last, but not least, the asset of flexibility. In addition, the ease of up-scalability of the required application technologies lowers the threshold for new players to enter this field. These efforts have resulted in the creation of technologies which are approaching the stage of first industrialization initiatives. These industrial activities target in first instance the market of consumer applications where energy autonomy can be ensured by integrating these flexible solar cells on a large variety of surfaces. In order to have a real impact on the PV-market, additional progress is needed on the level of efficiency, stability and application technologies to allow also the application of these solar cell technologies for power generation on a larger scale. The OrgaPvNet coordination action consortium wants to foster necessary progress on these issues by integrating a number of leading institutions in this field in association with the main industrial players entering this field. We believe that a Coordination Action is an appropriate vehicle by which the isolated competences that exist around Europe in this field can be integrated, structured and organised. In this way a powerful Organic Photovoltaic Platform will be created that can sustain the leading R&D-position of Europe within this domain and in the end strengthen European competitiveness in a sector which is of high strategic relevance in ensuring a sustainable energy supply. Key actions to reach the above-mentioned objectives are: i) to promote interaction between scientists, ii) to take advantage of the previous experience of research groups, iii) to join forces to maximize the synergy between individual skills, thus obtaining the best achievable global results, and iv) to provide an appropriate communication channel between academic groups, SMEs and industrials. OrgaPvNet will contribute to this by: a) the exchange of information during the workshops organized by the network, (b) scientific exchange between partners by research visits of scientist and student grants, (c) Set-up of a web-based database containing news, resources, project results, reports, links, seminars, training, courses, job opportunities, grants, (d) Elaboration of a "Who is Who" Guide in organic photovoltaic field, (e) Elaboration of the European Organic Photovoltaic Roadmap: identification of scientific priority areas and formulation of research and development strategies.

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NAPOLYDE

NANO-STRUCTURED POLYMER DEPOSITION PROCESSES FOR MASS PRODUCTION OF INNOVATIVE SYSTEMS FOR ENERGY PRODUCTION & CONTROL AND FOR SMART DEVICES

Annual Report 2007

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Project- / Contract Number	NMP2-CT-2005-515846 / SER N° 03.0111-2
Duration of the Project (from – to)	01.11.2003 – 31.10.2008
Date	05.02.2008

ABSTRACT

NAPOLYDE consortium will develop new technologies for polymer or polymer-like films deposition at nano-scale precision supporting mass production and environmental friendly requirements. The work focuses on:

2 different scales (small and large surfaces)

- Microelectronics, energy and bio-medical application
- Roll-to-roll for steel and glass applications

2 different ways (wet and plasma)

- Nanolayering (nanolayer and multilayer systems)
- Nanoclustering (nanoparticle inclusions)
- Nanotexturing (morphology control, from nodule-like to ribbon-like)

Improved properties

- Barrier properties (liquid, gas, improved corrosion protection)
- Electrical properties
- Anti-scratch films
- Hydrophobic and hydrophilic properties
- Antireflective, IR, UV protection

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PECNet

CREATING A COMPETENCE CENTRE FOR THE SOLAR SPLITTING OF WATER BY MEANS OF HYBRID PV-PEC CELLS

Annual Report 2007

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Project- / Contract Number	101883 / 152316
Duration of the Project (from – to)	01.10.2006 – 30.06.2008
Date	02.02.2008

ABSTRACT

In Switzerland, internationally leading competencies exist, among others, in the areas of photovoltaics (PV) as well as in **photo-electro-chemical (PEC) water splitting**. The main aims of this project concern interdisciplinary and output-oriented **cross-linking of the competencies** and their further development within the **framework program** of the **EU-FP7**.

The PECNet approach covers four main stages: (i) transfer and thus securing of knowhow of withdrawing PEC knowhow carriers (**NaPECK library**), (ii) linking of PEC stakeholders with relevant thin-film PV specialists to a Swiss PEC water-splitting network (PECNet CH), (iii) collaborative development of a 4-7 year R&D plan for Switzerland, with international integration, and (iv) submitting of a 4+3 year research project under EU-FP7.

Since the dominant **challenges** of PEC water-splitting concern the material side of photo electrodes, the above mentioned work plan stages (i), (iv) and (iii) have been tackled according to timing constraints. Following a round of preliminary information and involvement of key **PEC stakeholders**, an effective project management team has been developed and a kick-off meeting conducted at the University of Basel.

A preliminary **R&D plan CH** has been developed, which aims – among others – to develop a new 10cm x 10cm hybrid PV-PEC demonstrator cell. As part of this, technology combinations and advantages, disadvantages, possibilities as well as potentials of different materials have been discussed. It is planned for **2008** that a **more detailed, common, national research plan** will be developed. Following on, three development path options – straight forward, innovative, visionary – will be judged in detail and prioritised.

During 2007, the **NaPECK library has been assembled**, national PEC knowhow thus secured, and a national **PEC center of competence "PEChouse"** established as well as started **at the EPFL**.

In addition, as a key achievement of PECNet during 2007, a comprehensive and internationally highly networked **PEC material research program** has been developed and submitted under **EU-FP7**. Though unsuccessful in its first attempt, an adapted proposal will be prepared under the guidance of PEChouse in 2008.

PECNet is a classical knowhow and technology transfer project (KTT) that has been well received both nationally as well as **internationally**. Further positive results are to be expected in 2008.

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BIPV-CIS

IMPROVED INTEGRATION OF PV INTO EXISTING BUILDINGS BY USING THIN FILM MODULES FOR RETROFIT

Annual Report 2007

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Project- / Contract Number	503777 / SBF 03.0046
Duration of the Project (from – to)	1.1.2004 – 30.06.2009
Date	January 2008

ABSTRACT

The results of the project will improve and widen the potential for the integration of solar (PV) energy systems into existing buildings. Special attention will be paid to architectural and aesthetic questions. Building integration of PV systems in most cases leads to a “high tech” and “modern” appearance of the building. This is caused by the typical window-like surface of most conventional PV modules. Regarding however that 90% of the building stock consists of longer existing, that means “old fashioned” buildings, it is evident that an aesthetically satisfying building integration of PV needs a lot of good will and creativity from planners and architects. In many existing building integrated PV systems the modules contrast with the building and its surroundings.

A European survey on the potential and needs for building integrated PV components and systems will identify the basis for the development of modules away from the glass /window-like appearance. In the project PV roof tiles, overhead glazing and façade elements based on CIS thin film technology will be developed and investigated, which have a modified optical appearance for better adaptation to the building skin. One of the ideas is optical decoupling of substrate and cover glass.

A complete roof tile system with thin film cells adapted to the visual appearance of conventional roof tiles and innovative connection and mounting will be developed. The work includes prototype fabrication and tests according to relevant standards and subsequent performance tests.

Novel overhead glazing includes semitransparent thin film modules optimised for daylight transmission. The back side appearance will be modified in order to represent the visible inner part of the building skin. For overhead and insolating glazing an invisible interconnection and for PV roof tiles a low cost connector will be developed. Project result will be PV modules and generators for improved building integration ready for industrial manufacturing.

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ISAAC-TISO TEST CENTRE

QUALITY AND RELIABILITY OF PHOTOVOLTAIC MODULES

Annual Report 2007

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Project- / Contract Number	36508 / 151135
Duration of the Project (from – to)	from October 2003 to December 2006
Date	December 2007

ABSTRACT

The aim of the "ISAAC-TISO Test Centre" is to control the quality and reliability of photovoltaic modules and to promote the use of BIPV products. The main activities 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.

In April 2007 the seventh quality audit, for the ISO17025 accreditation maintenance of the sun simulator, supervised by the Swiss Accreditation Service, was successfully passed.

During 2007 services for third-parties have increased significantly. A total of 342 indoor I-V measurement were performed. In addition for several modules other measurements were executed: 22 determination of the temperature coefficients; 21 I-V characterization at different irradiances (200, 400, 600 and 800 W/m²); 47 outdoor initial degradation (20-40 kWh/m²); I-V determination with multiflash method; Visual inspection and insulation test according to IEC 61215; Electrical continuity test; Bypass diode test. Moreover 4 energy rating comparison were performed.

In March 2006 a new 15 months test cycle (no.10) began and ended in June 2007. Stabilized power of c-Si module after 15 months is on average 3.7% lower with respect to Pn and ranging from -0.7% and -8.2% and thus all type of modules are in the warranty limits. Differences in annual energy production [kWh/kWp], of 14 different module types, with nominal power Pn as reference, reach 10% but are lower with respect to measured real power.

During 2007 collaborations with 6 institutes (either Universities and manufactures) have been achieved for the installation of systems equipped with MPPT3K testing devices which were developed by ISAAC-TISO.

The new information homepage on BIPV was completed with a database of BIPV product, BIPV fastening and system example (see www.bipv.ch).

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PERFORMANCE

ISAAC ACTIVITIES

Annual Report 2007

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Project- / Contract Number	n° 019718 EU: (SES6) – Integrated project
Duration of the Project (from – to)	01.01.2006 - 31.12.2009
Date	December 2007

ABSTRACT

The PERFORMANCE project, started in January 2006, is a 4 year project of the 6th European Framework programme. It covers all pre-normative aspects from photovoltaic module to system level and from instantaneous device characterisation and system measurement to their life-time performance prediction and assessment. The limitations of current indoor and outdoor calibration measurement technology will be investigated and precision will be improved, covering current technologies as well as new and advanced cell and module concepts. Methods will be developed to connect from measurements of module power to module energy production. In a third pillar, methodologies for the assessment of the life-time performance of PV modules will be developed. Based on all these work packages, a modelling and analysis programme will provide the analytical understanding of PV performance in the broad and systematic manner mentioned above. Following this work programme, the project will produce a consistent set of measurement and modelling methodologies to create the transparency needed for the European market and industry. Next to this significant scientific effort, intense involvement of all European companies along the value chain will be organised systematically through feedback loops. Project results will be fed directly into standardisation processes on CENELEC and IEC level. The project is divided into 8 sub-projects:

SP1 Traceable performance measurement of PV devices
SP2 Energy delivery of photovoltaic devices
SP3 PV system performance evaluation
SP4 Modelling and analysis
SP5 Service life assessment of PV modules
SP6 PV as a building product
SP7 Industry interaction and dissemination
SP8 Standardisation processes

The ISAAC institute is official partner of SP1, SP2 and SP4 and collaborates in SP6. Moreover it's work-package leader of SP4.4 entitled "Annual Energy Rating Production and Device Comparator". The scope of this report is to present the institute activities of the second project year.

General information about the project can be found under **http://www.pv-performance.org**

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EFFICIENCY AND ANNUAL ELECTRICITY PRODUCTION OF PV-MODULES

Annual Report 2007

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Project- / Contract Number	101431 / 151715
Duration of the Project (from – to)	November 2005 – April 2007
Date	January 2008

ABSTRACT

Efficiency data of PV-modules under actual operating conditions are of vital importance for reliable prediction of their annual electricity production. For measuring these data, an outdoor test facility was erected at PSI. It consists of a sun-tracker and a PC-based measurement system. The sun-tracker is used to orient test modules continuously towards the sun. The measurement system is designed for automated acquisition of current/voltage (I/V) characteristics, from which the efficiency is determined. I/V tests performed under constant irradiation, but different module temperatures, allow the temperature coefficient of the efficiency to be determined. Measurements under varying irradiation and varying air mass allow the efficiency in these conditions to be determined. At least some hundreds I/V characteristics per module are required to develop semi-empirical efficiency models, which allow an accurate calculation of the efficiency under all relevant operating conditions. From the efficiency models and local meteorological data, the annual electricity production of the modules at the site selected for the PV plant can be calculated. These data allow the expected cost of electricity generation for different modules to be calculated, and thus the type of modules with the highest yield-to-cost ratio for a specific installation site can be identified.

Testing and development of efficiency models were carried out for three commercial modules (SunPower SPR-90 with mono-crystalline cells, Kyocera LA361K51S with poly-crystalline cells and Jumao Photonics JM-050W-S4-G, with mono-crystalline cells).

Cell efficiencies under Standard Test Conditions, STC of 19.5%, 12.7% and 12.6% were found for the SunPower, Kyocera and Jumao modules, respectively. Efficiency maxima of 19.7%, 13.3% and 12.7% were observed at 519 W/m^2, 419 W/m^2 and 832 W/m^2, respectively. The efficiency of all modules linearly decreases with temperature. The temperature coefficients were found to be -0.0637, -0.0493 and -0.0507 percentage points/°C, respectively. The SunPower module has efficiencies practically independent over the whole irradiance and air mass range. The Kyocera module also performs very well under varying irradiation, but its red light sensitivity in the late afternoon decreases slightly more than that of the SunPower module. However, the Kyocera module tested is fairly old (acquired in 1994). Recent measurements on Kyocera's latest modules show a much better red sensitivity and a remarkably higher efficiency. The Jumao module also behaves fairly well under increasing air mass. However with decreasing solar irradiance, the efficiency decreases remarkably.

Using measured meteorological data from a sunny site in Jordan, the electricity production for the SunPower, Kyocera and Jumao modules were calculated. The yearly output of South-oriented, 30°-inclined modules was found to be 459, 299 and 283 kWh/(m^2 cell area). For sun-tracked modules, the annual output amounts to 636, 405 and 398 kWh/ (m^2 cell area). Due to the high efficiency of Sun-Power's SPR-90 module, the module area required for 1 kW output power (under STC) is only 5.9 m^2, whereas it turns out to be 9.7 m^2 for the 12.7 % efficient Kyocera module.

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PHOTOVOLTAICS SYSTEM ENGINEERING 2007-2010 (PVSYSTE 07-10)

Annual Report 2007

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Project- / Contract Number	102234 / 152840
Duration of the Project (from – to)	01.07.2007 – 30.12.2010 (subproject monitoring from 01.01.07)
Date	10. December 2007

ABSTRACT

Purpose and Goals of the project during 2007

- Continuation of long-term monitoring of PV plants.
- Start of development of a large solar generator simulator of 100 kW (V_{OC} = 810V / I_{SC} = 155A) for automated tests of grid-connected PV inverters up to 100 kW.
- Ongoing participation in national network of competence BRENET.

Most important results in 2007

- Continuation of the long-term monitoring projects (partly since 1992) without any interruption despite the period without contract between Jan. and June 2007. Inclusion of a new plant with 11 kWp with two new crystalline module technologies (Sharp NUS03E and Sanyo HIP-205NHE1) and the expanded part of PV plant Stade de Suisse (now 1.35 MWp instead of 0.85 MWp) in monitoring program.
- Control software extension for dynamic inverter tests with power ramps instead of only steps.
- Extension of the test software controlling the semi-automated inverter tests for automatic change of the test voltage in a student's diploma thesis in order to reduce the manpower cost during our inverter tests. With this software (after some further improvements) fully automated inverter tests with our PV generator simulator of 20 kW and the future 100 kW device should be possible.
- Start of development of a linear PV generator simulator of 100 kW (V_{OC} = 810 V / I_{SC} = 155 A).
- Confidential (paid) tests of different inverters for major PV companies. For the first time a special safety test according to VDE 126-1-1 performed at our PV laboratory at a new device for an inverter manufacturer was accepted by the German "*Berufsgenossenschaft Elektro*".
- Organization of the second annual meeting of the international technical committee on PV systems (IEC TC82). The meeting of working group WG 6 (components) took place on Oct. 29th and 30th and that of WG3 (systems) on Nov.1st and 2nd. During these meetings, the sophisticated test infrastructure available at the PV laboratory was demonstrated to the delegates.
- An international workshop on dangerous DC arcs and live demonstration of the arc detector developed by the PV laboratory took place on Oct. 31, 2007 at BFH in Burgdorf with 44 participants from many countries. Organization was in co-operation with IEC, Swissolar and Electrosuisse.
- 2 own conference contributions and co-authoring at 2 further contributions at the 22nd EU PV conference in Milano, 2 contributions (one own, one co-authored) at the 22nd PV symposium at Staffelstein/D and a contribution to the 7th Swiss national PV conference at Emmenbruecke.
- New extended book about PV systems technology (in German, in color) published in Sept. 2007

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SIWIBU / SIMIBU

SOLAR INVERTER WITH INTEGRATED BACKUP

Annual Report 2007

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Project- / Contract Number	101807 / 152227
Duration of the Project (from – to)	October 2006 – December 2007
Date	6. December 2007

ABSTRACT

Conventional grid feeding solar inverters have to switch off during grid outages. This fact is inconvenient in regions with frequent power outages or where high supply quality is required. A feasibility study is performed for an inverter with basically three functions:

- Direct grid feeding of PV power
- Uninterruptible Power Supply (UPS) for dedicated appliances during grid outages
- Additional grid support from battery storage during peak demand hours

Contents of the study are an evaluation of existing inverters with similar functions, a market study for UPS devices, determination of potential market segments and barriers for market entry as well as the development of a technical concept together with the company Sputnik Engineering AG.

The field of application of SIWIBU is not only seen in industrial countries with feed-in tariffs for Photovoltaics but also in emerging nations in Africa and Asia where severe problems with grid stability exist and where at the same time renewable energies are supported by international development programs. SIWIBU also answers to the demand of developing countries for stand-alone power stations that can be integrated into the grid, once it will be available. Although the market potential is visible, it is difficult to predict how fast and with what level of effort this un-tabbed potential may be explored.

The initial results show clearly that the product can be produced under the given targets related to cost and operational flexibility. Expanding the UPS operation time by connecting the PV-array to the UPS battery and the guarantied grid support during peak load time looks quit attractive. Evaluation results of the electricity supply situation in California show a high potential for this operation mode. A key finding is, that the value of the entire solar supply increases, if the supply during peak hours is guarantied.

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SOS-PVI: SECURITY OF SUPPLY PHOTOVOLTAIC INVERTER

COMBINED UPS, POWER QUALITY AND GRID SUPPORT FUNCTION IN A PHOTO-VOLTAIC INVERTER FOR WEAK LOW VOLTAGE GRIDS

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Project- / Contract Number	SUSTDEV-1.2.3
Duration of the Project (from – to)	01.10.2005 - 31.12.2008
Date	December 2007

ABSTRACT

The SoS-PVi project aims at developing an inverter, dedicated to the injection of photovoltaic energy into low voltage grids, with special features so that first, the impact on the grid of the very quick fluctuations of sun irradiation is minimised and even more, the PV system provides grid support on demand and secondly, the end user is protected against poor power quality and outages of the grid.

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PV-BUK

OPERATION AND MAINTENANCE COSTS FOR PHOTOVOLTAIC SYSTEMS

Annual Report 2007

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Project- / Contract Number	102070 / 152575
Duration of the Project (from – to)	1. März 2007 – 31. Januar 2008
Date	13.12.2007

ABSTRACT

Several organisations in Switzerland assume for PV systems maintenance costs of 12 to 16 Rp./kWh. These costs are not only higher than the maintenance costs of thermal or hydraulic power plants but also higher than the power generation costs for conventional power (hydro, nuclear, coal). This would mean, that PV systems can't compete with conventional power plants due to their high maintenance costs.

Goal of the project PV-BUK was to determine the costs for facility management, to estimate the future cost development and to propose activities for further decrease of the operation and maintenance costs for photovoltaic systems. The study was financed by the Swiss Federal Office for Energy, the utility of Zurich (ewz) and the Energiefachstelle Basel. Project partner were the companies ENVISION, BE Netz and project leader Enecolo AG. Additionally the work was coordinated with the diploma thesis „Betriebs- und Unterhaltkosten von PV-Anlagen" from Mr. Reich, University of Biberach.

In 2007 information about the actual cost situation was collected by literature study, but also in interviews and surveys with PV experts and PV owners. Afterwards, all results were discussed at a workshop with about 20 Swiss PV experts. The results show that the operation costs per kWh energy yield decrease if the size of the PV system and the specific yield of the PV system increase. The major part of the maintenance costs is used for spare parts, especially for the inverter. Some matters of expense show a wide range of costs, e.g. roof rental, insurances and costs for administration.

In future the maintenance costs will decrease further, mainly because they are partly linked with the investment costs (e.g. insurance costs). Main optimisation potential exists in the monitoring of the PV systems and a fast service in case of malfunctions.

In 2008 the project team will propose average maintenance costs for several reference PV systems and a catalogue of measures to lower the maintenance costs of PV systems.

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UPDATE PHOTOVOLTAICS IN VIEW OF ECOINVENT DATA V2.0

Annual Report 2007

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Project- / Contract Number	101805 / 152224
Duration of the Project (from – to)	01.12.2006 - 30.06.2007
Date	January 2008

ABSTRACT

In this project, the data for photovoltaics in the ecoinvent database have been updated on behalf of the European Photovoltaics Industry Association and the Swiss Federal Authority for Energy. Data have been collected in this project directly from manufacturers and were provided by other research projects. LCA studies from different authors are considered for the assessment. The information is used to elaborate a life cycle inventory from cradle to grave for the PV electricity production in grid-connected 3kWp plants in the year 2005.

The inventories cover mono- and polycrystalline cells, amorphous and ribbon-silicon, CdTe and CIS thin film cells. Environmental impacts due to the infrastructure for all production stages and the effluents from wafer production are also considered. The ecoinvent data v2.0 is used as background database.

The report investigates the life cycle inventories of photovoltaics, comparing different types of cells used in Switzerland and analysing also the electricity production in a range of different countries. It is also discussed how the environmental impacts of photovoltaics have been reduced over the last 15 years, using the CED indicator. The consistent and coherent LCI datasets for basic processes make it easier to perform LCA studies, and increase the credibility and acceptance of the life cycle results. The content of the PV LCI datasets is publicly available via the website www.ecoinvent.org for ecoinvent members.

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STUDY OF THE POTENTIAL OF THE USE OF QUANTUM DOT SOLAR CONCENTRATORS IN PHOTOVOLTAIC SOLAR ENERGY CONVERSION

Annual Report 2007

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Project- / Contract Number	101806 / 152225
Duration of the Project (from – to)	01.11.2006 - 30.06.2007
Date	January 2008

ABSTRACT

One of the most promising application of semiconductor nanostructures in the field of photovoltaics might be planar photoluminescent concentrators. Even for diffuse solar radiation considerable concentration factors might be achieved. Such devices have originally been designed on the basis of organic dyes and might benefit from a considerably improved lifetime when replacing the organic fluorescent substances by inorganic semiconductor nanocrystals, so-called quantum dots.

Quantum dot containing nanocomposite thin films are synthesized at EPFL-LESO by a low cost sol-gel process. In order to study the potential of the use of quantum dot solar concentrators in photovoltaic solar energy conversion, reliable computer simulations are needed.

A tool for ray tracing simulations of quantum dot solar concentrators has been developed at EPFL-LESO on the basis of Monte-Carlo methods that are applied to polarization-dependent reflection/transmission at interfaces, photon absorption by the semiconductor nanocrystals and photoluminescent reemission.
Together with the knowledge on the optoelectronical properties of suitable photovoltaic cells, such simulations allow to predict the total efficiency of the envisaged concentrating PV systems, and to optimize pane dimensions, photoluminescent emission frequencies, and choice of PV cell types.

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CENTER OF COMPETENCE FOR BUILDING INTEGRATED SOLAR INSTALLATIONS

CONCEPT

Annual Report 2007

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Project- / Contract Number	102014 / 152494
Duration of the Project (from – to)	1. Februar 2007 - 30. Juni 2007
Date	29.01.2008

ABSTRACT

More and more solar installations are integrated in the building. These installations not only produce energy but also fulfil functions of the outer building layer. In such installations a good quality of the mounting system is very important.

In a first step a concept was worked out how the quality of mounting-systems with view to several aspects as statics, water-resistance, etc. shall be checked. The discussion among several involved universities and other key persons leaded to the proposed building of a working group.

The working group BiSolNet (competence network among several universities) shall be active in research and development, quality assurance and certification, information, studies.

The definition of the test procedures with international coordination shall be one of the first projects.

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THE SWISS CONTRIBUTION TO THE IEA PVPS PROGRAMME - TASK 1

Annual Report 2007

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Project- / Contract Number	11427 / 152 582
Duration of the Project (from – to)	01.01.2007 – 31.12. 2007
Date	14.01.2008

ABSTRACT

The Swiss contribution to the PVPS Programme includes:

1. **National Survey Report**, a summary of developments in the market and political areas. The report's data is integrated into the IEA's **Trends in Photovoltaic Applications Report**
2. Acquisition of Swiss contributions to **PV Power**, distribution of the magazine to approx. 280 addresses in Switzerland
3. Targeted search for **new contacts** in the PV area
4. Contributions/organizations to/of national and international **workshops**
5. **PR-work** in Switzerland. Reference to the programme's international publications

The results of these activities include:

4. **National Survey Report** (NSR) based on the statistics provided by the Swiss Association of Solar Professionals and the Swiss Association of Utilities (grid-connected installations)
5. Distribution of the **PV Power Magazine** in May and November
6. 2 **Task 1 meetings** in Zacatecas, Mexico and Tokyo, Japan
7. 2 Workshops in Milano (September) and Fukuoka (December), Workshop contribution in Zacatecas
8. Webmastering support for www.iea-pvps.org

Work still to be done:

9. Workshop organization at the PV conference in Valencia (Sept. 2008)
10. Participation at PV Finance workshop in Kuala Lumpur

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THE SWISS CONTRIBUTION TO THE IEA PVPS PROGRAMME - TASK 2 - 2007

Annual Report 2007

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Project- / Contract Number	14805 / 152583
Duration of the Project (from – to)	January 2007 - December 2007
Date	11.01.2008

ABSTRACT

Switzerland takes part in the Photovoltaic Power Systems (PVPS) programme of the International Energy Agency (IEA), Task 2. The overall objectives of the Task 2 is to improve the operation, sizing, electrical and economic output of photovoltaic systems and components by collecting, analysing and disseminating information on their technical and economic performance and reliability, providing a basis for their assessment, and developing practical recommendations. The actual work of Task 2 is organised in four active Subtasks.

Activities of Phase III, 2004 - 2007

Subtask 1: Performance Database (enrichment and dissemination of the performance database). This tool has now worldwide more than 3'000 users form 90 different countries. It is being updated at least once a year by the expert-group. The database is now available on-line at the public website http://www.iea-pvps-task2.org.

Subtask 5: Technical Assessments and Technology Trends of PV Systems.
This Task is developing knowhow and experience concerning the long-term reliability as well as the user-awareness of PV systems and ways to analyse and predict the performance of PV systems.

Subtask 6: PV System Cost over Time (Activity leader Switzerland).
The global economical survey aims at gathering information on plants, technical performance, maintenance and cost of as many PV systems as possible. With an Internet-based survey tool performance and economic data was collected over the past year. A report was published at the end of the year 2007 [2].

Subtask 7: Dissemination Acitivities, Educational Tools.

This project has been supported by the members of the IEA PVPS Pool Switzerland

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SWISS INTERDEPARTMENTAL PLATFORM FOR RENEWABLE ENERGY PROMOTION IN INTERNATIONAL COOPERATION (REPIC)

Annual Report 2007

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Project- / Contract Number	SECO UR-00123.01.01
Duration of the Project (from – to)	March 2004 – June 2007 (Phase I)
Date	January 2008

ABSTRACT

The Swiss State Secretariat for Economic Affairs (SECO), the Swiss Agency for Development and Cooperation (SDC), the Swiss Federal Office for the Environment (FOEN) and the Swiss Federal Office of Energy (SFOE) have been operating the interdepartmental platform for the promotion of renewable energy in international cooperation since 2004. The REPIC-Platform contributes to the implementation of global climate protection agreements and to a sustainable energy supply in developing and transition countries, as well as in Switzerland, and represents an important part in the implementation of the Swiss policy for sustainable development on the international level. The REPIC-Platform thereby represents an important contribution to the creation of a coherent policy and strategy in Switzerland, for the promotion of renewable energy in international cooperation.

The specific goals of the REPIC-Platform in relationship with renewable energy in international cooperation are:

1. Information and awareness of the stakeholders
2. Knowledge of local framework conditions and improvement of capacities
3. Project promotion and project realisation
4. Contribution to international networks
5. Coordination and quality control

The measures of the REPIC-Platform are subsidiary to national and international promotion instruments which already exist. The measures are meant to support these instruments, especially in the area of finance (project lines of the governmental agencies involved, mixed credits, WB, IFC, GEF, and similar) and climate policy instruments (Kyoto-mechanisms). Furthermore, the measures of the REPIC-Platform should provide for synergies between activities from the private sector and the civil society.

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IEA PVPS TASK 10 - SWISS CONTRIBUTION

Annual Report 2007

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Project- / Contract Number	101562 / 151862
Duration of the Project (from – to)	February 2006 – December 2008
Date	December 2007

ABSTRACT

The challenge for Task 10 is to translate the results of the research on PV in built environment (buildings + grid) and to expand the work to a wider range of stakeholders necessary to mainstream urban-scale applications. Several stakeholder values must be combined in order for urban scale PV values to exceed the price and become a sustained market of urban energy solutions. Switzerland is active in subtask 2 (Urban Planning, Design and Development) and 3 (Technical Factors).

Subtask 1 (Economic and institutional factors) led to the completion of the report "Value analysis" detailing the various types of added values brought by photovoltaics (environment, peak shaving, jobs, replacement of building elements). The report "Promotional drivers for PV" analyses the different promotional scheme for PV and the offer/demand requirements for a growing PV market.

For subtask 2 (Planning, design and development), a standardized analysis of the present and future urban policy related to PV was developed, discussed with the foreign partners and distributed. Workshops with planners, architects, and investors were organized in Neuchâtel and in Zurich to fill the questionnaire for Switzerland. Japan answered for 3 cities and Sweden for one.

In subtask 3 (Technical factors), a visualization tool was elaborated to illustrate the interaction between PV installations and electric grid. A report entitled « Urban BIPV in the New Residential Construction Industry » was prepared, evaluating the market outlook based on the national building activity. A detailed plan was elaborated for the investigation of the economic consequences for a local utility (in Neuchâtel) of a strong PV penetration, leading to 100% coverage of the demand of a sunny summer day (possible situation in 2030).

In subtask 4, the Lisbon Idea Challenge on urban PV design was conducted for the second time.

The linked European project PV-Upscale went online with its PV-database collecting tens of PV installations of the participating countries.

Swiss representation at the two Task 10 meetings (in Freiburg (D) and in Fukuoka (J)) was ensured, as well as at the Madrid joint meeting Task 10 – PV-Upscale (UE project).

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IEA SHC TASK 36: SOLAR RESOURCE KNOWLEDGE MANAGEMENT

GLOBAL RADIATION FORECAST AND TURBIDITY CLIMATOLOGY

Annual Report 2007

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Project- / Contract Number	101498 / 151784
Duration of the Project (from – to)	July 2005 – June 2010
Date	10.12.2007

ABSTRACT

In the framework of IEA Solar Heating and Cooling (SHC) Task 36 Meteotest investigates mainly the possibilities and quality of global radiation forecast. In the second year the validation of the global radiation forecast of Meteotest's operational MM5 model (30 km resolution) was continued. The root mean squared error for a 36 hour forecast was about 50%. Next year a more detailed validation and the introduction of a high resolution WRF (2 – 10 km resolution) model as well as PV production forecast are planned. Additionally a new turbidity climatology has been built. It is already included in Meteonorm Version 6 and will be used also in other radiation models.

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PHOTOVOLTAIC STANDARDS

Annual Report 2007

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Project- / Contract Number	Swissolar
Duration of the Project (from – to)	1.1.2007 – 31.12.2007
Date	10.12.2007

ABSTRACT

The worldwide use of Photovoltaic IEC standards supports international trade of uniform high-quality PV products, systems and services and assists conformity assessment such as certification and issuing quality label(s). International standards establish objective specifications that both buyer and seller can rely on. For buyers, they widen the range of choices and lower costs, primarily because they often increase the number of competitors. For sellers, global standards broaden the number of potential customers and reduce the cost of meeting their needs.

The Scope of IEC TC82 is to prepare international standards for systems of photovoltaic conversion of solar energy into electrical energy and for all the elements in the entire photovoltaic energy system. In this context, the concept "photovoltaic energy system" includes the entire field from light input to a solar cell to and including the interface with the electrical system(s) to which energy is supplied.

TC 82 has six active working groups developing standards for the photovoltaic industry. Some of the current work program topics include: safety of inverters and charge controllers, islanding prevention measures for grid connected PV Systems, design qualification and type approval of solar modules, on site IV curve measurements, minimum requirements for system documentation, commissioning tests, and inspection requirements for grid connected PV systems, requirements of PV arrays. Under the administrative lead of TC 82 is a Joint Coordination Group with TC 21, TC 88 and TC 105 which is developing a series of new standards dealing with various aspects of renewable energy system integration and project management.

In Switzerland, there is an ever increasing number of important manufacturers for machineries needed for the PV module production lines, plugs to be used in PV DC arrays, grid connected and stand-alone inverters, alu-profiles for mounting PV modules and laminates, and turn key operators as well as many consulting and engineering companies. Next to a direct involvement in the IEC work, all relevant documents are discussed in detail in the national standard committee TK82, in order to formulate Switzerland's interest in adequate, simple and effective standards for PV. In 2007, the TK has grown again to 15 experts, showing increased interest in standards.

The strategic decision during last TC82 meeting on elaborating standards to avoid dangerous arcs is of interest to Prof. Heinrich Häberlin. Swissolar has successfully organized a workshop to avoid danger from potential arcs in PV DC-array cabling. Multicontact had, in close collaboration with other plug mfg, successfully finished drafting a standard for plugs to be used in PV DC arrays.

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PV ERA NET

NETWORKING AND INTEGRATION OF NATIONAL AND REGIONAL PROGRAMMES IN THE FIELD OF PHOTO-VOLTAIC (PV) SOLAR ENERGY RESEARCH AND TECHNOLOGICAL DEVELOPMENT (RTD) IN THE EUROPEAN RESEARCH AREA (ERA)

Annual Report 2007

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Project- / Contract Number	CA-011814-PV ERA NET
Duration of the Project (from – to)	1 October 2004 – 30 September 2008
Date	December 2007

ABSTRACT

PV ERA NET is a European network of programme coordinators and managers in the field of photovoltaic solar energy (PV) research and technological development (RTD). The consortium comprises major key stakeholders in the field of national and regional RTD programmes involving photovoltaics (PV). The consortium comprises 19 participants from 13 states and regions with more than 20 national RTD programmes (or parts of programmes) and three regional RTD programmes.

The mission of PV ERA NET is to carry out activities towards networking and integration of national and regional programmes in the field of PV RTD in the European Research Area (ERA).

The overall strategic objective of PV ERA NET is to strengthen Europe's position in photovoltaic (PV) technology by improving the cooperation and coordination of PV RTD programming efforts across Europe, supporting long-term perspectives in European research policies as well as supporting related policies in order to establish a strong European Research Area and to create a durable structuring effect and impact in terms of coherence, innovation and economic growth.

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FLAT ROOF INTEGRATION CPT SOLAR

Annual Report 2007

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Project- / Contract Number	100493 / 150604
Duration of the Project (from – to)	From August 2003 to December 2006
Date	11/12/2007

ABSTRACT

This study is based on an a-Si PV plant of 15.36 kWp (CPT Solar), installed and operational since December 2003. The plant is composed of flexible triple-junction amorphous silicon modules laminated together with a single ply roofing system. The CPT-plant has been integrated and thermally insulated on a flat roof of a professional school located in the south of Switzerland. The final result consists on an a-Si thermally insulated PV plant with a nearly horizontal position. For inter-comparison reasons, 3 small open-rack plants with a-Si and c-Si modules were installed near the main PV plant.

During the years 2006 and 2007 the main objective was to thoroughly investigate losses and gains, with respect to a typical south oriented and tilted open-rack solution, characterizing this type of installation. The global contribution of losses and gains are indicated comparing the CPT-plant performances with those of the three reference plants. Direct performance comparison of the thermally insulated CPT-plant with the open-rack a-Si reference plant (same module type and orientation as the CPT-plant) allowed highlighting of the important annealing and reduced Staebler–Wronski degradation effect observed on the thermally insulated modules. In fact, compared to open-rack installations, the thermally insulated plant displays higher working temperatures which enhance annealing effects during summer and reduce the S.-W degradation in the subsequent months.
Moreover, we were able to verify that the better thermal behaviour and annealing processes of a-Si compared to c-Si technologies could compensate a significant part of losses due to the nearly horizontal roof integration.

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FLEXCELL EXPERIMENTAL ROOF 2KW

Annual Report 2007

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Project- / Contract Number	
Duration of the Project (from – to)	1st march 2005 -
Date	18.02.2008

ABSTRACT

Today, crystalline silicon technology represents more than 90% of the photovoltaic (PV) market. Nevertheless, proper building integration requires special architecture and remains difficult on existing buildings without a massive and costly substructure to hold the PV modules. When one imagines a world wide massive spread of PV technology, the use of low cost recyclable material that can cover almost any roofing profile makes most sense.

The aim of this project is to demonstrate that thin-film flexible solar cells, encapsulated with low cost and recyclable plastic through a thermoforming process, is a solution for real and cost efficient building integrated photovoltaic (BIPV).

The roofing profile chosen for this demonstration project is the corrugated panel. While being the world's most used roofing profile, there exists no realistic technical solution to integrate crystalline silicon cells on corrugated tiles.

In this context, VHF Technologies SA has developed a methodology to produce series of plastic PV panels with the exact corrugation selected profile. The roof of the Yverdon's ice ring stadium has been selected as pilot site for the installation.

The 2.1 kW_p PV-installation has been achieved on March 2006, the monitoring under real working conditions allow validation of the developments and bring the opportunities to an industrialization phase.

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EKKHARTHOF ZERO-ENERGY SCHOOL BUILDING IN KREUZLINGEN

Annual Report 2007

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Project- / Contract Number	101787 / 152201
Duration of the Project (from – to)	Januar bis Dezember 2007
Date	07. Dezember 2007

ABSTRACT

The P+D project "Nullenergieschulhaus Heilpädagogisches Zentrum Ekkharthof Kreuzlingen" has the goal to document with electric meter measurements, to which degree the overall energy consumption of the new built zero-energy-house can be covered with solar electricity from the plant. In order that practice-related measuring data can be collected, there was no special instruction of the caretaker and the staff. The data set of the last year led to the following key data:

- From January to November 2007 the solar electricity production was nearly two times higher than the energy consumption of the building
- In summertime the energy gain of solar electricity is four times higher than the electricity consumption of the building
- In wintertime (Feb. 07) the solar plant can cover about 65% of the energy consumption of the building
- In wintertime (Feb. 07) the heat pump could be run during the day in 12% of all days with 80% solar electricity
- In summertime the whole building could be run during the day in 90% of all days with 80 % and more solar electricity

Furthermore, the analysis shows that the solar plant would produce enough electricity, that as an alternative to the night operation, the heat pump can be run during the day with a part of solar energy

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ROOF-MOUNTED INSTALLATION ON A GYMNASIUM IN WIESENDANGEN WITH AMORPHOUS THIN-FILM MODULES

Annual Report 2007

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Project- / Contract Number	101788 / 152202
Duration of the Project (from – to)	01.08.2006 – 15.03.2008
Date	December 2007

ABSTRACT

In 2005 the companies Biohaus in Germany and E. Schweizer AG in Hedingen brought the new system Biosol XXL on the market. This is a new PV system for roof integration which consists of the successful Solrif-frame (P&D Project DIS 29909/69804) and large-area solar modules basing on triple junction solar cells from Unisolar. The complete module covers an area of 1.9 m2.

In December 2006 a Biosol XXL PV test system was installed on the roof of the gym „Gässli“ in the municipality of Wiesendangen. The publics attention was called to the PV system with a media event and pupils were involved into the installation of the system. It could be demonstrated that installation with a Biosol XXL system is fast and efficient. The uniform and aesthetic area of the PV modules is very suitable for building integration. In 2007 the PV system functioned without any problems.

Goal of the year 2007 was to measure the performance of the PV system and to compare it with a crystalline PV system on the nearby maintenance depot. It should be verified, if the high performance as promised by Unisolar really could be achieved.

Due to several defects of the measurement equipment, measurement data of the first half of 2007 are not complete. Main cause for the defects was, that several times water could intrude into the electrical cabinet in the cellar of the gym and destroyed the data logger. In June 2007 the source of the defects was detected and the data logger was installed in an other part of the cellar. Since then, all necessary data can be measured in a resolution of 15 minutes. Hence it was determined to extend the measurement period to spring 2008 to get a more complete data basis. Analysis of the measurements therefore will be done in early 2008 instead of in 2007.

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PREPARATION AND REALISATION OF THE TEST- AND PILOT INSTALLATION SOLIGHT

NEW LIGHT-WEIGHT FLAT ROOF PV MODULE MOUNTING SYSTEM

Annual Report 2007

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ABSTRACT

Almost all of the mounting systems for solar PV modules available on the market require additional weight to withstand heavy wind loads. As the roof of many building is not used for any other purpose, it is an ideal place to mount solar PV modules. However, many modern buildings are built to reduce material and labour to build the roof structure, therefore reducing the cost of the building. They are built to just satisfy the demands of structural engineering, but most of the times hardly allow any additional weight on them.

These roofs prohibit any placing of PV-solar modules on them. Many roofs in Switzerland, however, furbish as an uppermost surface a layer of 3 to 8 cm of loose gravel. This gravel functions as an UV-protection and wind load proofing of the watertight foil below it.

The main goal of the project is to sum up the experience of the previous project and to implement a pilot and test installation to put the findings of SOLight to the proof. In the first phase of this new project, which has been successfully completed in 2003, the design has been refined, tested and completed. Till end of November 2007, the realisation of the pilot installation has been successfully executed with SOLight structures to test the system for its usability in real outdoor condition, e.g. under special consideration of wind and snow loads. This will help to learn important lessons on the application and the usability of this new mounting approach.

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PHOTOVOLTAIC ENERGY STATISTICS OF SWITZERLAND 2006

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Date	Mai 2007

ABSTRACT

The project reported in this paper is the follow up work to the PV Energy Statistics and Quality Assurance Project mutually funded by the Swiss Federal Office of Energy and the Swiss Electricity Producer and Distribution Union of Switzerland. This work has determined key figures for both PV performance and overall PV electric energy contribution in Switzerland.

In 2006, about 250 new PV plants were connected to the grid in Switzerland; 50 more than last year. The Swiss PV Market's installed peak power of 2.5 MWp didn't reach last year's record of 4.3 MWp. However, considering actual market conditions, it's still a remarkable result.

On account of 3.5% higher irradiation in 2006, compared to that of the last 20 years, the annual yield of all Swiss PV installations reached 845 kWh/kWp; slightly higher than the annual average of about 800 kWh/kWp. The systems overall reliability and operational availability are still considered to be very good for these kind of technical systems.

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17.6 KWP INSTALLATION WITH THIN-FILM MODULES ON THE FLAT ROOF AT THE CNB BUILDING OF THE ETHZ

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Duration of the Project (from – to)	June 2003 – December 2006
Date	December 2007

ABSTRACT

The CNB-building of the Swiss Federal Institute of Technology (ETH), Zurich, is located downtown. As a part of the renovation of the building, a new photovoltaic installation has been realized.

The building is subject of local historical monument preservation and protection codes. Therefore, the PV modules are of one colour and installed as symmetrical as possible.

The installation has a power of 17.6 kW peak and consists of standard thin-film-modules. A display in the new cafeteria provides information about the service of the installation.

Together with the engineering office energiebüro ag, BE Netz installed the plant in June 2006.

The objective to integrate the photovoltaic installation in the roof landscape as decent as possible has been accomplished. With 18'409 kWh in the first year of production, the performance is at least even to standard cristallin solutions.

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PHOTOVOLTAIC FACADE

MOUNTING SYSTEM FOR THIN-FILM-MODULES AT FACADES

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Date	December 2007

ABSTRACT

Thin-film-modules are as well interesting for the application in facades. At the Technical School of Engineering and Architecture Lucerne several questions to stability by fixing standard thin-film-modules with the Aluhit-P-mounting-system were investigated and judged in view to relevant norms.

In Goldau, a 3.1kW-pilote installation at the south and east-facades of a transformer-building was realized. It demonstrates the façade-application of thin-film-modules. The data-acquisition shows a higher energy production compared to the calculation at the south façade, while the energy production of the east façade was lower than expected.