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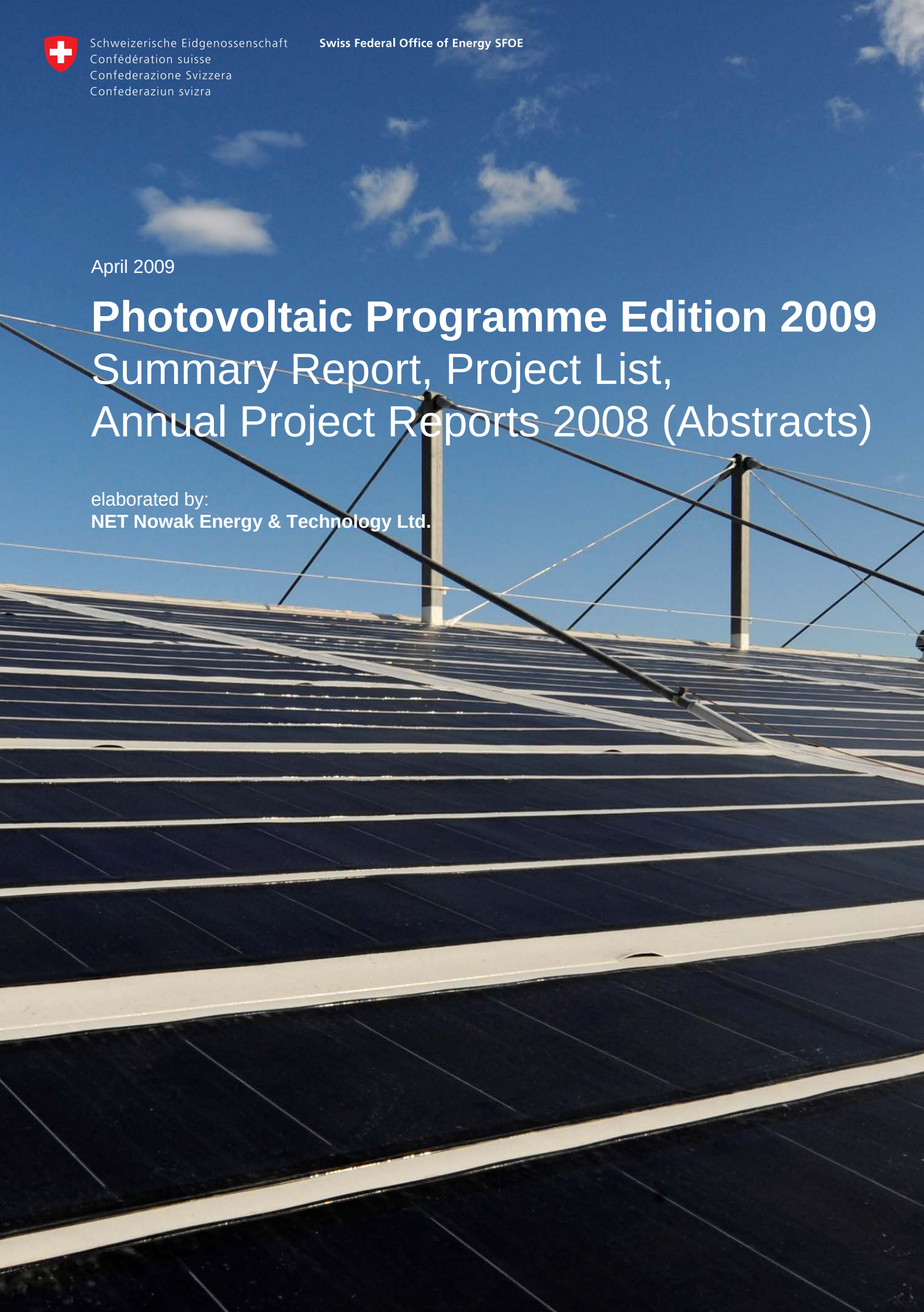

April 2009

Photovoltaic Programme Edition 2009
Summary Report, Project List, Annual Project Reports 2008 (Abstracts)

elaborated by:
NET Nowak Energy & Technology Ltd.

Cover:

The biggest Solar power plant made of roofing membrane with integrated thin-film photovoltaic cells in Switzerland, Stadium Gründenmoos in St.Gallen, venue of the international known horse riding tournament CSIO Switzerland. Surface: 1200 square meter. Owner: Sankt Galler Stadtwerke. year: 2008

Foto + Project: energiebüro® ag / zürich / Switzerland - for Solar Power Plants

Prepared by:
NET Nowak Energy & Technology Ltd.
Waldweg 8, CH - 1717 St. Ursen (Switzerland)
Phone: +41 (0) 26 494 00 30, Fax. +41 (0) 26 494 00 34, info@netenergy.ch

on behalf of:
Swiss Federal Office of Energy SFOE
Mühlestrasse 4, CH - 3063 Ittigen postal addresse: CH - 3003 Bern
Phone: +41 (0) 31 322 56 11, Fax. +41 (0) 31 323 25 00 office@bfe.admin.ch www.bfe.admin.ch

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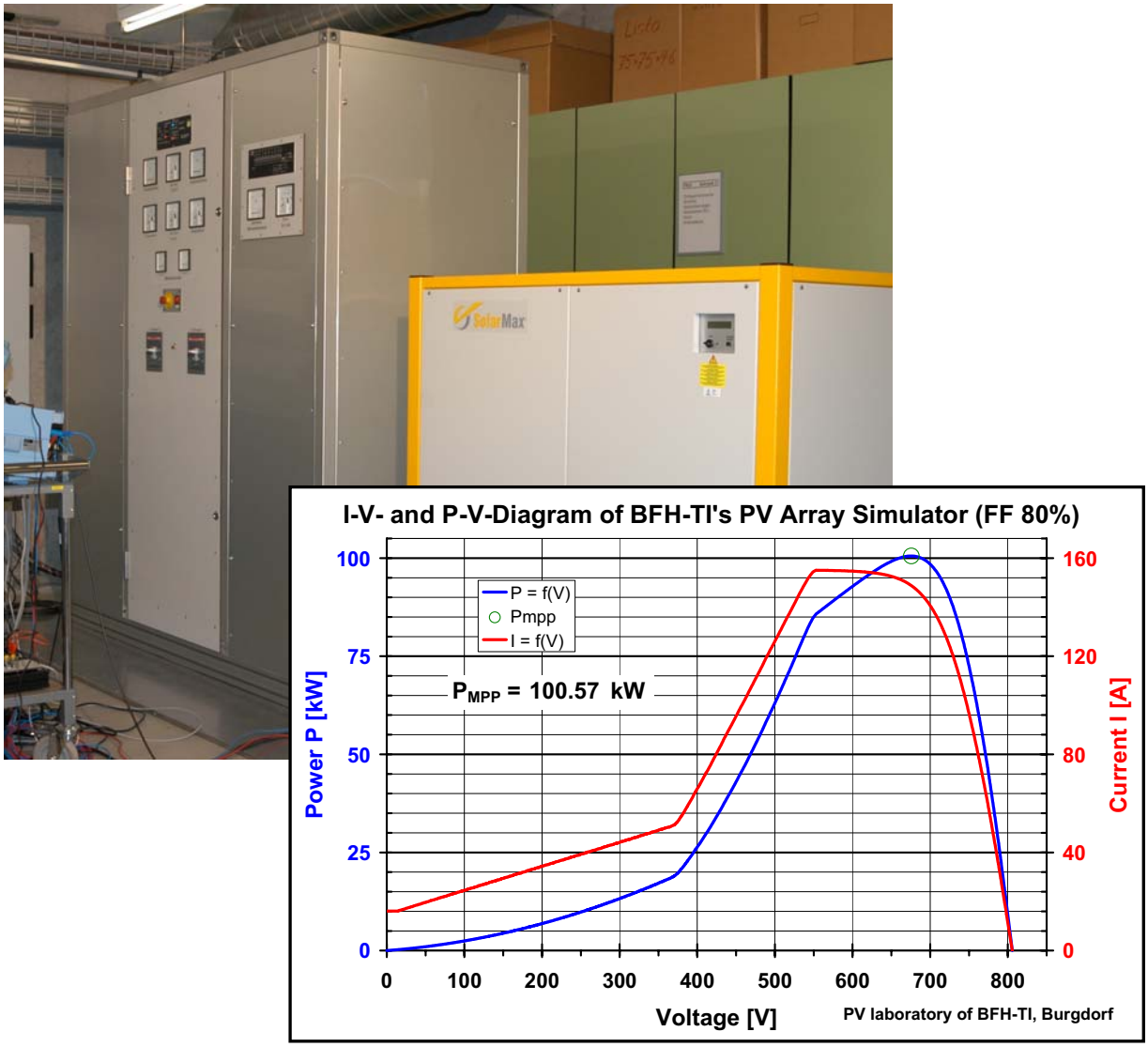
Contents

PHOTOVOLTAICS PROGRAMME

Summary Report on the Research Programme 2008

Stefan Nowak
stefan.nowak@netenergy.ch



100 kW solar generator simulator

The photovoltaic laboratory of the University of Applied Sciences in Burgdorf has realised a 100 kW photovoltaic array simulator which is the largest of its kind in the world. This instrument allows to measure the characteristic efficiency curve and the Maximum Power Point Tracking (MPPT) of inverters up to a power of 100 kW (photo: BFH-TI).

Contents Summary Report

1. Programme priorities and targets

In 2008, photovoltaics experienced both worldwide as well in Switzerland a further upswing. The Swiss Photovoltaic programme was positively affected by the general upswing, as the interest of research and industry in the subject of photovoltaics is still high and Swiss industrial activities were further intensified. As was to be expected, the global depression did have an effect on the photovoltaic industry in the last quarter and a slow-down in developments had to be noted. Due to the feed-in tariff for electricity from new renewable resources that was introduced during 2008, application oriented questions regarding photovoltaics became additionally important. As a result of the wide support for the photovoltaic research programme, the previous extent of the programme was exceeded in 2008. Continuing growth in the international photovoltaic market provides an important basis for the clear expansion of the photovoltaic industry in Switzerland. The competence of Swiss photovoltaic research is being demanded more than ever and more often also leads to industry-oriented projects.

Thus, the Photovoltaic programme has remained closely oriented towards industrial implementation and international competitiveness, both for products and for the preceding research activities. In 2008 about 50 research and development projects including remaining pilot and demonstration activities 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) [59], the main objectives of the Swiss Photovoltaic programme for the period 2008 to 2011 are [60]:

- **Lowering the costs** of solar cells and modules
- **Cost target** for 2011: module 3 CHF/W, systems 5 CHF/W
- **Increasing efficiency** (solar cells)
- **Lowering material and energy input**
- **Simplification and standardisation** of electrical system technology, increasing the service life and reliability of inverters
- **Increase of availability and variety** of industrial products

The Photovoltaic programme is therefore divided into the following sections

SOLAR CELLS OF THE FUTURE

As before, work on **thin film solar cells** continued to focus on the following principal thin film materials: **silicon** cells (amorphous, micro-crystalline), cells based on **compound semiconductors** (CIGS); and **dye sensitised cells.** The fundamentals for **organic and polymer solar cells** as possible long-term technology options are gaining in importance on the whole and are, at the same time, moving from the concept phase to the development of 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 2008, industry projects for larger production plants for thin-film solar cells were pushed onwards. Also, solar cells on flexible substrates are gaining in importance.

In accordance with the CORE Energy Research Master Plan 2008 - 2011 [59], the goals for the solar cell area are:

- Industrial manufacturing of solar cells and modules on the basis of thin-film technologies with the goal of developing competitive production processes and products (cells, modules)
- Medium and long-term material options for solar cells of the future (e.g. organic and polymer solar cells) with the aim of increasing international co-operation in these areas in Europe
- Manufacturing processes for thinner wafers with the aim of a reducing wafer thickness down to 150 µm

The goals for the solar cell area are further specified in the detailed Photovoltaic research master plan [60]. As far as funding is concerned, research work on solar cells forms one of the most important parts of the Swiss Photovoltaic programme. Accordingly, various methods of providing support are used.

MODULES AND BUILDING INTEGRATION

In the Photovoltaic programme, the solar modules area is closely related to applications concerning **building integration (BIPV)**. Module technologies which fit in well with the solar cells developed in Switzerland are in the foreground. Research topics in this area can include new or improved processes for the production of solar modules (e.g. packaging, electrical connections, new materials) as well as their characteristics (e.g. long-term stability, mechanical, optical and thermal characteristics).

In accordance with CORE Energy Research Master Plan 2008 - 2011 [59] the goals to be reached in the solar modules and building integration area are:

- Genuine integration of thin-film solar cells into new products for building integration with the goal of industrially producing new photovoltaic building components, in particular those using thin-film technology
- Product synergies between photovoltaics and building technology, both in the building envelope area as well as for technical services in the building (e.g. fuel cells), with the aim of finding new implementation approaches for the optimisation of the production and use of energy in buildings.

ELECTRICAL SYSTEMS TECHNOLOGY

Electrical system technology, in particular in the inverters area, is well developed and there is a wide range of products on the market, including various successful products from Switzerland. The further development necessary in the inverter area is mostly provided by industry. On the other hand, **quality assurance** in this area of technology must be guaranteed along with the procedures required (e.g. certification of products). Particular needs result from general progress made in electrical systems technology and new applications.

New options in electrical system technology are emerging as a result of continuing innovation in the area of domestic electrical installations. In the future, information on the operating states of various domestic technical equipments will be exchanged on an increasing scale.

In the past, it was the electrical system components in a photovoltaic installation which were those components which represented the weakest links and which were responsible for numerous failures. Although this situation has considerably improved in recent years, the long-term characteristics of photovoltaic components and installations remains an important concern which should be examined at greater depth within the framework of a number of limited analyses. The reliability and safety of photovoltaic components and installations are areas which have recently received an increased amount of attention (e.g. arcing).

A topic becoming more important in the future will be the integration of photovoltaics into the electricity grid. This concerns questions on individual installations to a lesser extent; it is rather the interaction of a large number of photovoltaic installations with the electricity mains that is at the focus of attention. In connection with the expected development of Smart-Grids, new requirements placed on photovoltaics and associated new opportunities could emerge. Specific questions concerning photovoltaics are primarily of interest here.

According to CORE's Energy Research Master Plan 2008 - 2011 [59], the goals for the field of electrical systems technology are:

- New system components for grid-connected installations, stand-alone and hybrid systems with the aim of providing integrated product solutions for combined grid-connected, stand-alone and hybrid operation
- Decentralised power generation systems, energy storage and energy use with the aim of providing active consumption control

ACCOMPANYING TOPICS

In this area, which partially supplements technological topics, the general conditions necessary for the further market development of photovoltaics are in the foreground, e.g. with respect to advanced instruments for the planning and monitoring of photovoltaic installations, the quantification of environmental aspects etc. In order to guarantee market relevance, such projects are to be carried out in close co-operation with the corresponding stakeholders.

A second category of projects in this focus of interest are new possibilities for combining applications of photovoltaics with other forms of energy; for example with other forms of solar energy (solar architecture and solar thermal energy), or with concepts concerning sustainable mobility (electric cars, solar

boats etc.) or in combination with other power resources (e.g. hydrogen, thermophotovoltaics). Here too, good co-ordination with the corresponding funding bodies is to be guaranteed and actual development work is to be defined appropriately. This means that both the primary use of the energy and specific development requirements must be identified.

INTERNATIONAL INSTITUTIONAL CO-OPERATION

Basically, international co-operation is being striven for in all the fields discussed up to now and is, accordingly, also well established. In addition to this project-oriented international co-operation, co-operation has also to be continuously guaranteed at the level of the institutions themselves. Previous experience and benefits gained from this co-operation for Switzerland can be considered in general to be very good. Accordingly, providing continuity in this area of international co-operation is a strategic element of the Photovoltaic programme. Faced with rapid international developments in the area of photovoltaics, this co-operation is, in the future, to be continued in all fields.

The following international institutions are in the foreground:

- European Commission (EC) - framework research programmes, SET plan;
- EU PV Technology Platform (PV TP) - Strategic Research Agenda, SET plan;
- PV-ERA-NET – co-operation between European research programmes;
- IEA PVPS – global research co-operation within the framework of the IEA;
- IEC - standardisation activities;
- Organisations concerning development co-operation: international organisations, e.g. gtz, GEF, IFC, WB.

2. Work completed and results achieved in 2008

CELL TECHNOLOGY

During the 2008 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 and 7th Framework Programmes for research as well as in CTI projects are important elements here.

a) Thin film silicon

The most important developments in the thin-film silicon area are being carried out at the University of Neuchatel (IMT), the EPFL (CRPP) as well as at the oerlikon solar (Truebbach and Neuchatel) and VHF-Technologies (Yverdon) companies and represent the most important activities in the Photovoltaic programme. PSI and the EMPA Thun are complementing these efforts with new approaches.

At the IMT at the University of Neuchatel, a new phase of the *Silicon thin-film solar cell and modules* project [1] was begun during the year under review. The goals of this 4-year SFOE project include the further lowering of the costs of thin-film silicon solar cells, whereby amorphous silicon, SiGe compounds and micro-crystalline silicon are the subjects of research. The progress to be achieved is to allow manufacturing costs of <1 €/Wp at an efficiency of >10% to be reached. The project is defined along the four areas of materials, processes, components (devices) and reliability and includes the corresponding deposition systems as well as extensive analytical methods (Fig. 1). Co-operation with industry primarily concerned the oerlikon solar and VHF technologies companies, who are implementing the processes developed at the IMT in their products. New on the scene as far as industrial partners are concerned is the Roth&Rau company, which has gone into an extensive research partnership with the IMT. The following results from the year under review are worth mentioning:

Materials: On the basis of the results obtained in previous years for amorphous and micro-crystalline single junction solar cells on glass substrates and the development of intermediate reflector layers on the basis of ZnO and SiOx, a further increase the efficiency of the micromorphous solar cell was striven for. Using an intermediate reflector layer of SiOx the efficiency of micromorphous solar cells with a surface area of 1 cm^2 was increased to 13.1% in the year under review. For transparent, conducting ZnO oxide layers (TCO), good stability was achieved in the humidity-heat test (85ºC, 85% relative humidity).

Processes: In the year under review emphasis was placed on the production of microcrystalline silicon at high deposition rates. As a result, a microcrystalline single solar cell with an efficiency of 7.1% was produced at a deposition rate of 1 nm/s which is considerably higher in comparison with earlier efforts. Further activities were concerned with the production of nano-textured substrates as well as laser scribing of the solar cells for monolithical connections.

Components: Apart from the micromorphous solar cell with an efficiency of 13.1% already mentioned, amorphous (p-i-n) tandem solar cells on glass with an initial efficiency of 9.8% and a stabilised efficiency of 8.3% were produced. For use on plastic substrates, micromorphous (n-i-p) solar cells using a ZnO intermediate reflector were produced with a stabilised efficiency of 10.1%.

Reliability: In the case of this newly-established activity at the IMT, the question of the reliable packaging of various types of solar cells is being examined. The relevant work includes the adhesion of polymers on glass, water diffusion in packaging layers for solar cells, the water content of polymers as well as compatibility with electrical contacting and back reflector layers.

The CTI *Flexible Photovoltaics – next generation high efficiency and low cost thin film silicon modules* project [2] was continued in the year under review at the IMT at the University of Neuchatel and at 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. Using a backside, diffusely scattering dielectric reflector, a substrate structuring and an amorphous cell structure in tandem configuration should increase the efficiency of the industrial products to 6%. Good progress was made on small surfaces with single-junction cells and tandem cells with stabilised efficiencies of 7.3% respectively 8.0% being achieved. A further CTI project at the IMT is concerned with *Translucent conducting oxides on the basis of ZnO* [3].

Work on the *THIFIC - Thin film on crystalline silicon* project [4] supported by the Axpo Natural Power Fund was continued at the IMT. In this project, ultra-high efficiency solar cells with an efficiency of 20-22% are being aimed for. 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% had already been achieved. For this solar cell, the interface between the crystalline silicon wafer and the amorphous thin-film solar cell plays an essential role; this interface should be atomically sharp in consideration of the structure of further layers. In the year under review, the better understanding of this interface led to the production of solar cells with an open cell voltage of 700 mV.

In the new EU project *HETSI: Heterojunction solar cells based on a-Si / c-Si* [5], the IMT also working at an international scale on the topic of heterojunction solar cells. For the first time, this project combines 12 European enterprises and research institutes from the fields of crystalline silicon and thin-film silicon solar cells in such a project. The project complements the research into the above-mentioned boundary surface and the structure of the amorphous solar cell layer built on it. With regard to the industrial use of the project's results, a new, automated, large-area deposition system (410 x 520 mm^2) was installed at the IMT.

The EU *FLEXCELLENCE* project [6] under Swiss co-ordination by IMT and with participation of VHF-Technologies was successfully concluded in the year under review. This project was concerned with flexible solar cells on plastic and metal substrates and the production technologies needed. In this work, three different approaches were examined for roll-to-roll coating, in particular microwave PECVD (Plasma Enhanced Chemical Vapour Deposition), Hot Wire CVD (Chemical Vapour Deposition) and VHF PECVD. The IMT and VHF-Technologies are concerned with the last of the three procedures mentioned. At the IMT, a micromorphous tandem cell was implemented using PECVD on plastic (PEN). with a stabilised efficiency of 9.8% in the year under review (Fig. 2).

In the integrated EU project *ATHLET* [7] 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 year under review, an initial efficiency of 13.3% was achieved for micromorphous solar cells using the above-mentioned SiOx intermediate reflector layer. Using the KAI-M industrial double chamber system recently installed at the IMT micromorphous solar cells with an initial efficiency of 11% and a stabilised efficiency of 9.4% were produced.

At the end 2008, the IMT changed its institutional affiliation from the University of Neuchâtel to the Swiss Federal Institute of Technology EPFL; the Neuchatel site is, however, to be retained.

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: Multi-pass single - chamber processing at VHF-Technologies (photo: IMT).

A new CTI project at the CRPP of the EPFL is concerned with the *Development of a new PECVD reactor for the deposition of thin-film solar cells* [8].

The new SFOE-project *Two-dimensional nano-structures for silicon solar cells* at PSI [9] takes a look at the question of finding optimal ways of producing two-dimensional optical diffraction structures on silicon thin film solar cells. First of all, the corresponding equations are to be solved by means of numerical methods; later, such structures are to be experimentally implemented. In the year under review, various algorithms and their convergence behaviour were examined.

In a new EU project named *High-Ef – Large-grained, low-stress multi-crystalline silicon thin-film solar cells on glass by a novel combined diode optical laser and solid-phase crystallisation process* [10], EMPA Thun is working on a new process for the production of highly-efficient thin-film silicon solar cells. The process combines the crystallisation of an amorphous silicon layer caused by laser melting with solid-state epitaxial growth. In this way, a competitive process for the production of thin film solar cells with an efficiency >10% is to be realised. The technology is to be used by the German CSG Solar manufacturing company. The work at EMPA was concerned with the characterisation of the microstructure as well as the mechanical qualities of silicon produced.

b) 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* [11] examines 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 CIGS solar cells efficiency and reliability are to be improved, too. An efficiency of 12% on polyimide substrates is being aimed for. Further, alternative back-side contacts are to be developed.

The deposition systems are being developed in-house and optimised with respect to process repeatability and in-line deposition. 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. For this purpose, the evaporators employed for the individual materials were analysed with respect to evaporation profiles and layer thickness. For a substrate width of 25 cm, an acceptable homogeneity was achieved.

For the back-side contacts, alternatives to conventional methods with molybdenum were developed; materials favoured include transparent oxide layers (ITO) and metal nitrides. With ITO as a back contact, flexible CIGS solar cells on polyimide with an efficiency of 11.9% were produced. With Ti/TiN as a back contact, the efficiency of individual solar cells was increased to up to 13.1%, so that with these alternative back-side contacts, and when compared to the previous reference value and world record of 14.1% (with Mo back contact), interesting perspectives have been opened.

In the SFOE project *Thin film CIGS solar cells with a novel low-cost process* [12] the Thin-film Physics Group is developing a completely new production method for CIGS solar cells. Making use of an ion-exchange reaction, copper from watery cupreous or organic solutions is being integrated into thin indium selenide films. The latter are produced using co-evaporation. The structure and composition of the layers produced in this way were analysed using surface-analysis methods. The organic solution allows the more reliable and more reproducible integration of copper, but, however, does not up to now lead to higher efficiencies of the CIGS solar cells thus produced. The CIGS solar cells produced

using the diluted solutions have, up to now, attained an efficiency of 4.1%, those produced using the organic solution an efficiency of 3.5%.

The EU *LARCIS* project [13] is concerned with large-area processes for the industrial production of CIGS solar cells. Here, the Thin-film Physics Group at the ETHZ is, on the one hand, concerned with the optimisation of back-side cell contacts on the basis of molybdenum as well as alternative materials, in particular TiN and ZrN and their combination with molybdenum. On the other hand, the influence of the type and quantity of the sodium treatment on the characteristics of the CIGS solar cells was examined more closely in the year under review. For this purpose, the thickness of the sodium layer was varied between 0 and 40 nm. Optimum results were obtained with a sodium layer of 20 nm. Up to now, the deposition of the sodium layer has mostly been implemented using subsequent treatment (post deposition treatment PDT). In the year under review, co-evaporation of sodium was examined; this has the advantage that it can be better integrated into an in-line process. In this way, an efficiency of 12.5% was achieved for the CIGS solar cells. A further aspect concerned the production of buffer-free CIGS absorber layers (the buffer layer usually consists of a thin layer of CdS). Making use of a final surface coating of $I_{nx}Se_{y,}$ a buffer-free CIGS solar cell with an efficiency 12.0% was produced, which is somewhat lower than that with a CDS buffer layer.

In the integrated EU project *ATHLET* [14], 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. In the year under review, CdS-free CIGS solar cells on polyimide with an efficiency of 10.1% were produced using In_2S_3. For production of the In_2S_3 buffer layer, the use of ultrasonic spray pyrolysis was examined for the first time. The best CIGS cells achieved an efficiency of 12.4% on glass. With an eye on CIGS tandem cells, appropriate layer structures were manufactured. The photocurrent for a tandem cell structure can be adjusted by modification of the Ga content.

In the CTI project *Laser-patterning of CIGS solar cells on flexible foils for monolithic integration* [15] which was carried out in co-operation with Flisom and the Bernese University of Applied Sciences for Technology and Computer Science (Institute for Applied Laser Technology), the Thin-film Physics Group at the ETHZ examined the laser structuring of flexible CIGS solar cells for the monolithic integration to form solar modules. In the year under review, the laser system was installed and individual laser-scribes were examined. A prototype version of a monolithically-connected, flexible CIGS solar module was produced (Fig. 3).

In the *Development of flexible CIGS modules with metal grids* project [16] supported by the Axpo Natural Power Fund, the start-up company FLISOM developed a connection system for CIGS solar cells on flexible substrates that uses metallic lattices. Various connection processes are being examined. Here too, a demonstration module was manufactured (Fig. 4).

At the end of 2008, the Thin-film Physics Group changed its institutional affiliation from the ETHZ to the EMPA Duebendorf and is re-establishing its laboratories there.

Figure 3: A prototype of monolithically inter-connected CIGS module on polymer film (photo: ETHZ).

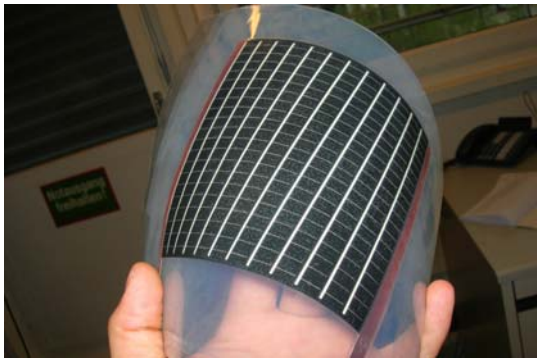


Figure 4: Flexible monolithic demonstrator modules with grid interconnected cells (photo: FLISOM).

c) Dye-sensitised and organic solar cells

Dye-sensitised solar cells and, in particular, organic solar cells are at present gaining in importance both nationally and internationally; in Switzerland, too, a number of research institutes are now beginning to deal with this topic.

The development of dye-sensitised nano-crystalline solar cells was continued at the LPI (ISIC) at the EPFL. Important work on this subject is being carried within the framework of the new EU *ROBUST DSC* project [17]. In this project, the most important European academic and industrial organisations in the field of dye-sensitised solar cells are working together with the aim of developing materials and production processes for a solar module with an efficiency of 7%. In parallel to this, more basic research with new materials and configurations is being carried out which targets a laboratory efficiency of 14%.

With the support of the Gebert Ruef foundation, the Institute of Computational Physics (ICP) at the Zurich University of Applied Sciences (ZHAW), together with the LPI at the EPFL, is working on the new *ModSol - Modelling, simulation and loss-analysis of dye-sensitised solar cells* project [18]. Here, the optical, physical and electrochemical behaviour of the dye-sensitised solar cell is to be modelled using various modelling methods and represented in graphical form. Initial work is concerned with the optical modelling and a one-dimensional model of the surface of the dye-sensitised solar cell.

The EMPA Duebendorf is establishing its competence in the field of organic solar cells in its laboratory for functional polymers. In the *Organic Photovoltaic Devices* project [19], the combination of cyanine dyes with PCBM blends (Fullerene derivates) as well as the nano-structuring of the transition between donor and acceptor materials is being examined. The micro-structure can be created in dimensions under 100 nm, whereby the opto-electronic qualities can be selectively influenced.

In the area of European trans-national research co-operation, a call for tender named POLYMOL on Polymer and Molecular Solar Cells was issued within the framework of the PV-ERA-NET project [61] (see below) in which the Swiss Photovoltaic programme also took part. From a total of 8 project proposals, 4 were selected for implementation, two of which with Swiss participation. In January 2009, the *HIOS-Cell* project [20] will start at the EMPA Duebendorf which is closely related to its work in the field of organic solar cells mentioned above. Further, EMPA Duebendorf is continuing work on a CTI feasibility study concerning *Transparent and Flexible Solar Cell Electrodes made from Precision Fabric* [21].

A further new project within the framework of the POLYMOL call for tender has begun at the Zurich University of Applied Sciences (ZHAW): *Apollo - efficient area organic solar cells via printing* [22] combines European competencies in the field of plastic electronics in order to develop simply producible organic solar cells as a result. The aim of the work is to attain the ability to produce these solar cells just like printed circuits. From Switzerland, Ciba and the CSEM are involved, together with project leader ZHAW, this institute being concerned with the cell modelling.

The EU project *OrgaPvNet* [23] 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* [24] project stands for interdisciplinary research activities in the field of nanostructured 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%. Here, the operational procedures necessary and the material properties obtained are of particular interest

Solaronix was involved in the EU's *FULLSPECTRUM* project [25] which was concluded in the year under review. FULLSPECTRUM is one of the first integrated projects in the photovoltaics area; it combines various approaches that can be taken to make better use of the radiation spectrum in one project (III-V multi-junctions, thermophotovoltaics, intermediate band cells, molecular concepts); whereby efficiencies of up to 40% are being striven for. In this project, Solaronix is, in particular, involved in supporting work in the module for new molecular concepts. This involves the examination of the part played by dye-sensitised solar cells in 2-photon processes and in flat concentrators. Solaronix is concerned here with the measurement of voltage-current characteristics, spectral sensitivity and the stability of flat concentrators. In the year under review, a stability of up to 2 years for exterior weathering was proven for the flat concentrators developed.

A related concept is being examined in a new CTI project called *Development of efficient luminecent concentrators based on inorganic/organic nano-materials for applications in solar energy conversion* [26] by the Institute for Inorganic Chemistry at the University of Zurich in co-operation with Optical Additives. In this project, zeolyte dyes are used, which, as a result of their supra-molecular organisation, should guarantee efficient concentration. In the year under review, preliminary operational steps were optimised.

In the CCEM *ThinPV* project [27] co-ordinated by EMPA Duebendorf, which is also supported by swisselectric research, the various actors in the Swiss thin-film solar cell research community are brought together in one project. Together, work is carried out on selected questions on various technologies. In the field of thin-film silicon solar cells, the understanding of the plasma-physical processes involved is being addressed, whereby the corresponding analytical methods were developed at the IMT in Neuchatel (optical emission spectroscopy, infrared absorption spectroscopy and laser scatter). A further subproject is concerned with hybrid tandem cells using CIGS and dye-sensitised solar cells as well as with the optimisation of the individual cell components, in particular the dye-sensitised solar cell. The record efficiency achieved for a short time for a stacked dye-sensitised/CIGS tandem solar cell lies at 15%; in the year under review, the monolithic integration of this tandem cell was developed. Here, the efficiency achieved was 9.9%. A third subproject is concerned in particular with the training of junior researchers; in connection with these efforts, a workshop on the subject of "*A look into solar cells*" [62] was successfully held in the year under review

The Institute for Solar Technology SPF at the University of Applied Sciences in Rapperswil HSR, together with the SFOE's *PECNet* [28] project, set up a competence centre for the solar splitting of water by means of hybrid PV-PEC cells. Primarily, the project is technologically set in the photoelectrochemistry 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 collected. Together with the Energy Centre, the PEChouse is being built up as a co-ordination centre at the ISIC of the EPFL. The project was concluded in the year under review.

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 concepts of utilities, further work is being done on the reduction of costs for solutions with a stronger integration aspect. The feed-in tariff for solar power introduced in 2008 takes the varying costs of the different types of installation into account and is to favour building-integrated systems. As a series of systems have been successfully developed for mounting modules on buildings (see P+D section also) over the past years, work is now increasingly being concentrated on the development of the solar modules themselves.

As a follow-up project to the EU *BIPV-CIS* project [29] concluded in the previous year, Swiss Solar Systems (3S) has continued work on a project concerning a roof-integrated module within the framework of the SFOE *SMARTTILE* project [30]. Using the solution proposed, a roof element is to be developed which reduces manufacturing costs as a result of the mounting system used and the extended functionality proposed (e.g. pluggable connections) and will allow industrial mass production. Further aspects concern the vertical seal, the transition to conventional roofing tiles, the use of standard laminates, the provision of a solution without aluminium frames and tools for mounting as well as a suitable substructure. In the year under review, requirements concerning conformity testing and the consequences for product design were concentrated on; here, requirements concerning fire behaviour are of particular importance.

At the LTC (IMX) at the EPFL, the CTI *Ultralight Photovoltaic Structures* project [31] was concluded in the year under review. The initial goal was the development of a very light and stable photovoltaic module (<1 kg/m2) using a sandwich structure for application in Bertrand Piccard's *SOLARIMPULSE* [38] solar aeroplane. Implementation ideas were developed for mono-crystalline silicon and dye-sensitised solar cells. Here, the mechanical behaviour under load and the packaging of the solar cells was in the foreground of research work. In 2007, VHF Technologies were introduced as an additional partner in the project. In this way, the application of the project's results in the area of building integration was also brought into perspective.

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.

The ISAAC at SUPSI continued the *Centrale ISAAC-TISO 2007-2010* project [32] in the year under review. The laboratory, which is certified in accordance with ISO 17025 for measurements with its class A solar simulator, received its 8th official accreditation in October 2008. A further solar simulator from Pasan was installed. The number of measurements of the voltage-current characteristics of solar modules that are carried out as a service for third parties was clearly increased once more with a total of 458 measurements being made. Also, for particular products, further parameters were determined such as temperature coefficients or the performance of the products at various levels of insolation.

The 11th test cycle of exterior measurements began in the year under review with 13 commercial modules (4 mc-Si, 4 sc-Si, 1 HIT, 1 a-Si/a-Si tandem, 1 a-Si/µc Si, 2 CIS). The measured performance of the crystalline solar modules at the start of the test cycle of 15 months were on average -2.6% lower than the values specified, whereby this deviation lay between +0.5% and -10.5%.

A specific development concerns the correct internal measurement of thin-film modules. Depending on technology and manufacturer, pre-treatment was necessary here, e.g. using electrical current or light. In many cases, a spectral correction is also needed which is determined on the basis of measurements made on spectral response characteristics.

The ISAAC was involved in work for the EU *PERFORMANCE* project [33] 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. The measuring equipment at the ISAAC was improved in the year under review. 6 European test laboratories with different infrastructures carried out a Round Robin Test on thin-film modules in the year under review. The maximum powers measured at the various laboratories showed a spread of up to ±7%. The largest deviations were explained by mismatched current conditions. In the comparisons of the various laboratories, amorphous single junction solar cells showed the least deviations. The largest deviations were found in the case of a-Si triple cells and CIGS solar cells (Fig. 5).

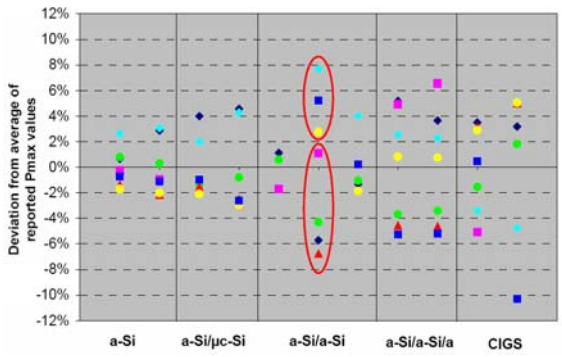


Figure 5: Discrepancies of reported P_{MAX} data at STC plotted for each test sample (photo: ISAAC).

Figure 6: 100 kW solar generator simulator with a 100 kW inverter from Sputnik (photo: BFH-TI).

Special work is dedicated to the measurement of the energy production of solar modules subject to different levels of insolation; various procedures were tested for this task. These results are being integrated into work on the new IEC 61853 standard. Important new publications were made as part of the work package on building integration [63-65].

In the year 2009, the ISAAC at SUPSI will be making important investments in order to build up the infrastructure necessary for *Accredited measurements of modules in accordance with the IEC* [34]. On account of the great demand for such measurements and the long-standing professional competence available at the ISAAC, the time is favourable for the realisation of such a project.

At the photovoltaic laboratory at the University of Applied Sciences in Burgdorf, the *Photovoltaic System Engineering PVSYSTE 2007 – 2010* project [35] was continued. Long-term measurements partly made continuously since 1992 on a current total of 70 PV installations were continued. In co-operation with ADEV Burgdorf, the module comparison installation built in 2007 was extended with four further crystalline module technologies and integrated into the monitoring project (total 20.3 kW_p), so that 6 different module technologies are now in use under virtually identical conditions at this location. For semi-automatic inverter testing, the test software for the 20 kW solar generator-simulator was altered for fully-automatic tests. A large part of project activities was dedicated to the development and commissioning of the new 100 kilowatt linear solar generator-simulator. This solar generator-simulator is probably the largest one of its kind worldwide. Up till now, efficiency characteristics for three different ranges of voltage for inverters up to a maximum power of 92.2 kilowatts have been made on a 100 kW inverter (Fig. 6).

The investigations concerning the lightning-current behaviour of bypass diodes begun in 2006 were also continued in 2008 and theoretical analysis was further extended. After the successful conversion of the current-surge generator to provide impulse currents that conform more or less to standards, various bypass diodes in modules could also be tested in practice.

The EU *SOS-PVI (Security of Supply Photovoltaic Inverter)* project [36], in which Maxwell Technologies works as a Swiss partner, was concluded in the year under review. In this project, five prototypes of an inverter with integrated back-up function were developed. Together with the technical solution for the inverter, questions concerning load characteristics in specific electrical network conditions and the control systems necessary were also examined.

ACCOMPANYING TOPICS

The PSI was participating in international work on the topic of thermophotovoltaics (TPV), on the basis of the *FULLSPECTRUM* [37] EU integrated project. The project was concluded in the year under review. Based on previous projects, in the thermophotovoltaics 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 [38] 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 [39], 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 the year under review, steps have been taken towards implementation and construction in the case of both projects. 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.

INTERNATIONAL CO-OPERATION WITHIN IEA, IEC, EU

During the reporting period, participation in the IEA Photovoltaic programme (IEA PVPS) was characterised by continuity both at the project level and in the executive committee (ExCo) [66]. 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, *Exchange and Dissemination of Information on Photovoltaic Power Systems* [40]. In the year under review, a further national report on Photovoltaics in Switzerland up to 2007 [67] was published; on the basis of which the 13th edition of the annual international report on market trends in photovoltaics *("Trends Report")* in IEA countries was published [68]. This report has become an increasingly quoted reference and was once more used for the current analysis of photovoltaics [69-72]. A workshop was held at the 23rd European photovoltaics conference in Valencia on the topic of grid parity of photovoltaics. Further, contributions were presented on the topic of financing at workshops in Frankfurt and Kuala Lumpur. The *IEA PVPS Newsletter* [73] regularly informs on work in and around the IEA PVPS programme and is distributed to 250 addressees in Switzerland. Since 2008, the IEA PVPS website is being maintained and updated in Switzerland [74].

The Swiss contribution to IEA PVPS Task 2 *Performance, Reliability and Analysis of Photovoltaic Systems* [41] is provided by TNC. Formally, this project was concluded in the previous year - final reports were, however, first finished in the year under review. The PVPS *performance database*, that is still available online [75], contains data on photovoltaic 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. On account of the importance of quality assurance and the reliability of photovoltaic installations for the increasing market, work is being carried out on a Task 13 follow-up project on this subject. For this purpose, a workshop led by Germany was held in the year under review.

Within the framework of the inter-departemental platform (SECO, SDC, FOEN, SFOE) for the promotion of renewable energy and energy efficiency in international co-operation REPIC [76], 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. Within the framework of this project, meetings were held in Busan (Korea) in the year under review as well as Workshops in Tunis and Phnom Penh. Task 9 sets an emphasis on energy services in various fields of application and often deals with approaches which are not limited to photovoltaics alone [77]. The topic of water supply was further deepened in the year under review; for this purpose Task 9 was involved in an AfDB workshop in Tunis. 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 *Urban Scale Photovoltaic Applications* [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 [78] which pursued similar goals at the European level and which was concluded in the year under review. Switzerland elaborated a report on the topic of Urban PV policies. In addition, Task 10 completed various reports [79-83]. 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 within 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 presently newest IEA PVPS Task 12's work on *Photovoltaic Environmental, Safety and Health Issues* [45]. 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 PVPS Task 12, Switzerland is concentrating on the life-cycle analysis (LCA). In addition, Task 12 is also concerning itself with the recycling of photovoltaic modules. On the latter subject, the PV CYCLE association was set up, which published an important publication in the year under review [84].

Meteotest [46] and the *Groupe Energie* at the University of Geneva [47] 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 focused on the comparison of radiation forecasts made using various models.

SWISSOLAR represents Switzerland in the IEC's TC 82 on *Photovoltaic Standards* [48]. 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 (BOS) Components, Concentrator Modules). Switzerland is primarily involved in the working groups on non-concentrating modules, systems and BOS components. In every area of technology, standards are an essential component in product design, testing and in quality inspection. The rapidly-developing photovoltaic 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. In the year under review, 8 different standards were published [85-92]. In Switzerland, the work is being accompanied by TK 82 [93].

Participation in the EU's *PV-ERA-NET* project [49], which brings together the programme co-ordination offices and the ministries of 13 countries responsible under the ERA-NET scheme [94], was ensured by the Photovoltaic programme management (SFOE, NET Nowak Energy & Technology). 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. The first POLYMOL joint call for tenders on the subject of organic and polymer solar cells was completed in the year under review with 4 trans-national projects that have already begun their work. Switzerland was involved in this call for tender and two of the four projects approved are being worked on at the EMPA in Duebendorf [20], along with the Swiss partners ZHAW, CSEM and Ciba [22]. *PV-ERA-NET* was extended by a year in autumn 2008.

Another important topic was the Strategic Research Agenda (SRA) [95] published by the European Photovoltaic 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 area of photovoltaics, development time-scales for technology and economic efficiency as well as with respect to the relationships between private and public (national and EU) research. At present, an implementation plan is being developed.

3. National co-operation

At the national level, the diversity of the 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. The newly created Photovoltaic Executive Day was successful held for the first time in the year under review with decision-makers from photovoltaics research, Swiss industry and administrative bodies (SFOE, CTI, CORE).

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 2008 there were 9 and 3 projects in the 6th and 7th Framework Research Programmes of the EU, of which 3 are integrated projects (FULLSPECTRUM, PV-ATHLET, PERFORMANCE). Regular contacts occur with those responsible for programmes in EU countries, as also with those departments responsible in the European Commission.

Switzerland is represented in the European Photovoltaic Technology Platform [96] both in the steering committee as well as in individual working groups. Technology platforms are a new instrument, and are to allow wider support 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. Within the framework of the Strategic Energy Technology Plan (SET Plan) [97] 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 2020 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)

In the year under review just one new SFOE photovoltaic P+D project was started. Since 2003, a total of 5 new projects have been started. A further P+D project is being supported by the Axpo Natural Power Fund. The number of PV P+D projects is marginal in comparison with the period before 2003, when every year 10 or more projects were supported by the P+D programme. Fortunately, some of these 'old' projects still set certain accents in the current photovoltaic market. With only this small number of active photovoltaic P+D projects, an essential link is missing with regard to the transfer and application of research and development results in industrial products and processes and, therefore, to the market. This means that the effect of this part of the programme still remains subcritical. As a result, Swiss companies have been finding it increasingly difficult to bring new and innovative products in the field of photovoltaic applications onto the market for some years now.

The new *SMARTTILE* project [30] aims to carry out pilot tests with a new PV roofing element that is optimised for industrial manufacture and which can be mounted without the need for any tools.

The photovoltaic P+D projects still running mainly continue to handle the subject of the **Integration of Photovoltaics in Buildings.**

NEW P+D PROJECTS

- SMARTTILE (pilot application of a new roof-integrated photovoltaic system, that can be mounted without the use of tools and which is optimised for industrial production; Management: 3S Swiss Solar Systems [30]
- At Muensingen railway station, TNC implemented the world's first bi-facial photovoltaic noise protection barrier [50] along a railway line. It delivers a rated output of 7.25 kWp (front side) and 5.6 kWp (back side). The plant was financed by the local municipality, with the help of InfraWerkeMuensingen, the local power utility as well as the Canton of Berne. Since it was not necessary for the SBB (Swiss Railways) to install any standard glass noise protection elements at the photovoltaic installation's location, the SBB credited the municipality with the corresponding amount of money resulting from their lower expenditure (Fig. 7).

CURRENT P+D PROJECTS

As far as current projects are concerned, the measurements previously made within the framework of the project investigating the degradation and annealing behaviour of modules with amorphous cells confirm the assumption that further degradation can be stopped to a large extent by warming amorphous modules to certain temperature limits, or, using higher temperatures, can even be reversed. [51] (Fig. 8)

The measurements made at the zero energy-consumption Ekkharthof school in Kreuzlingen, (a building built to Minergie standards combined with photovoltaics and a heat pump) show that by the use of systematic load management in spring, summer and autumn a high correlation between solar power production and power consumption (including the heat pump) can be achieved [52]. (Fig. 10)

Current projects are (in chronological order):

Installations

- Degradation and annealing behaviour of modules with amorphous cells (measurements and analysis on the basis of flat roof integration CPT Solar; Management: ISAAC) [51] (Fig. 8)
- Practical testing of a backup inverter (grid-connected inverter with interrupt-free power supply during blackouts in a practice test; Management: Enecolo) [53]
- 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) [52] (Fig. 10)
- 2 kWp Flexcell® experimental roof with flexible amorphous solar cells integrated in a thermoplastic roofing element; Management: VHF technologies) [54] (Fig. 9)

Measurement campaigns

- Wittigkofen measurement campaign (detailed measurement and evaluation with data visualisation of an 80 kWp system mounted on a building facade in Wittigkofen; Management: Ingenieurbuero Hostettler) [55]

Studies - tools - various projects

- Swiss Photovoltaic Statistics 2007 (Management: Ingenieurbuero Hostettler) [56]

Figure 7: Bi-facial photovoltaic noise protection barrier (photo: TNC)

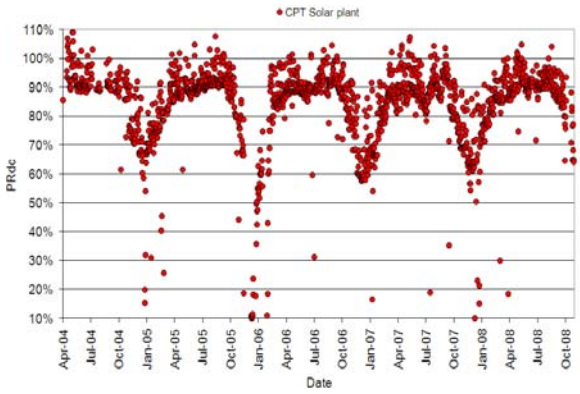


Figure 8: CPT Solar; thermally insulated amorphous PV Module: since 4 years without degradation effects (photo: ISAAC)

Figure 9: 2 kWp Flexcell experimental roof (photo: VHF-Technologies)

Figure 10: Ekkharthof zero-energy school building in Kreuzlingen (photo: Böhni Energie und Umwelt)

P+D PROJECTS COMPLETED IN 2008

In 2008, the following P+D projects were concluded (in chronological order):

Installations

- 12 kWp Solight pilot system (pilot realisation of two different Solight variants; Management: Energiebuero) [57]
- 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) [58]

6. Assessment of 2008 work and prospects for 2009

For photovoltaics, 2008 was a very dynamic and, to a large extent, successful year both nationally and internationally, although the global financial crisis and depression did have an effect on the rapidly growing photovoltaic industry. In a dynamic market characterised by high growth, the photovoltaic industry was able to continue its expansion for the present; one must, however, reckon with a reduced rate of growth for 2009 and the following years. The bottleneck in the availability of raw silicon supplies for crystalline silicon cells still indeed exists but signs of relaxation can be seen here. The trend towards lower system prices noted since 2007 has continued and it can be assumed that cost reductions will continue at a higher rate. Further announcements concerning investments to be made in thin-film technologies were made in 2008. For 2009, numerous new industry projects were announced whereby the first GWp units are being discussed. The total production capacity for thin-film modules in year 2009 could reach a figure of up to 5 GWp, whereby one must reckon with fact that the current financial crisis could at least delay some of the projects or even prevent their implementation. 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 discussion in the previous year concerning Swiss electricity supply legislation and the promotion of renewable forms of energy included in it, the topic of photovoltaics received great attention in Switzerland too. With the cost-covering remuneration (KEV) or feed-in tariff introduced in the year under review, high expectations were raised and, correspondingly, a large number of applications for financial support for projects were made. As a result of the cap currently valid, these applications now form a long queue of projects waiting to be included in the KEV. Although quantitatively very limited as far as photovoltaics is concerned, the KEV should nevertheless lead to a stimulation of the Swiss photovoltaic market and thus also further technological developments.

Swiss photovoltaics should be judged in the light of this situation: On account of their broad basis, research and technology are also at a high level when considered on the international scale. The position of the Swiss centres of competence in photovoltaics was further strengthened in the year under review; the global dimensions of the photovoltaic business requires, however, further steps to be taken in order to be able to keep up with international developments. A quantitatively sufficient business volume and a strong industry are crucial factors for success that will be of even more importance in the future. The transfer of technology to industry and an international focus are substantiated by numerous CTI and EU projects: In the year under review, 7 CTI and 12 EU projects with direct reference to photovoltaics could be noted. On the other hand, the lack of funding for pilot and demonstration projects and a market growing only slowly and in a limited manner constitute important disadvantages for market implementation in our own country. In spite of these difficult conditions, increasing industrial photovoltaic activity can also be noted in Switzerland. On the basis of surveys, it is estimated that the export volume in the Swiss photovoltaic area for 2008 is at least 1'500 million Swiss Francs. Together with the home market, the total turnover of the Swiss photovoltaic industry is estimated to be at least 1'600 million CHF.

The transfer of the results of Swiss photovoltaic research into industrial products is in recent years to be especially seen in the success story 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 progressed in concrete ways: 25 MW VHF-Technologies (Flexcell) in Yverdon and 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 Photovoltaic programme represent the scientific and technical starting point around which Swiss innovations and products can present themselves in a rapidly growing photovoltaic market. The long-term practical experience in the construction and operation of numerous photovoltaic systems 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 Photovoltaic programme will continue its attempts to preserve its critical mass and thus be able to make a meaningful impact 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 master plan defined by CORE for the period 2008 - 2011 forms the basis for the orientation of research in the photovoltaic area from 2008 onwards [59]. The corresponding detailed master plan was completed in the year under review and its implementation was approved by CORE in summer [60]. In this concept document, the most recent national and international developments are considered and the priorities of the next few years are defined.

The national exchange of information and experience gained continues to be an important topic in Switzerland. In June 2008, the first Photovoltaic Executive Day took place in Bienne with decision-makers from photovoltaic research, Swiss industry and the administration (SFOE, CTI, CORE) taking part.

The photovoltaic 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 photovoltaic scene was well represented with its contributions at the 23nd European Photovoltaic Conference in Valencia in September [98].

For 2009, it can be assumed that as far as photovoltaics is concerned the situation in the research area will remain dynamic. Photovoltaics is one of the areas of technology in which research is to be supported with a higher priority during 2009 (SFOE). This should allow a further increase in the competencies available in order to be able to meet - at least in part - the increasing demands being placed on research. The possibilities for further-going technological initiatives are to be pursued in the year 2009. Moreover, interesting prospects can be noted as a result the fact that the teams of researchers in Neuchatel and Zurich are changing their institutional affiliation so that, as a consequence, new developments can be expected to result.

7. List of R+D Projects

Annual Report 2008 available
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, A. Feltrin, F. Sculatti-Meillaud, S. Fay, F.J. Haug, V. Terrazzoni-Daudrix, R. Theron, R. Tscharner (christophe.ballif@epfl.ch) IMT, UNI-Neuchâtel, Neuchâtel: **New processes and device structures for the fabrication of high efficiency thin film silicon photovoltaic modules** (Annual Report) http://www.unine.ch/pv.

[2] F.J. Haug, (franz-josef.haug@epfl.ch), IMT, UNI-Neuchâtel, Neuchâtel: **Flexible Photovoltaics – next generation high efficiency and low cost thin film silicon modules** (Annual Report) http://www.unine.ch/pv.

[3] C. Ballif, (christophe.ballif@epfl.ch) IMT, UNI-Neuchâtel, Neuchâtel: **Development of a novel surface treatment of LP-CVD ZnO layers used as Transparent Conductive Oxide for thin film silicon solar cells** http://www.unine.ch/pv.

[4] S. De Wolf, S. Olibet, J. Damon-Lacoste, L. Fesquet, C. Ballif (stefaan.dewolf@epfl.ch), IMT, UNI-Neuchâtel, Neuchâtel: **High efficiency thin-film passivated silicon solar cells and modules - THIFIC: Thin film on crystalline Si** (Annual Report) http://www.unine.ch/pv.

[5] S. De Wolf, J. Damon-Lacoste, L. Fesquet, S. Olibet, C. Ballif, (stefaan.dewolf@epfl.ch), IMT, UNI-Neuchâtel, Neuchâtel: **HETSI: Heterojunction Solar Cells based on a-Si / c-Si** (Annual Report) http://www.unine.ch/pv.

[6] V. Terrazzoni, F-J. Haug, C. Ballif, (vanessa.terrazzoni@epfl.ch), IMT, UNI-Neuchâtel, Neuchâtel: **FLEXCELLENCE: Roll-to-roll technology for the production of high efficiency low cost thin film silicon photovoltaic modules** (Annual Report) http://www.unine.ch/flex.

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

[8] Ch. Hollenstein, (christophe.hollenstein@epfl.ch) EPFL - CRPP, Lausanne A new low ion energy bombardment PECVD reactor for the deposition of thin film silicon for solar cell applications http://crppwww.epfl.ch.

[9] D. Gablinger, R. Morf, (david.gablinger@psi.ch), PSI, Villigen: Zweidimensionale Nanostrukturen für Silizium-Solarzellen (Annual Report) http://www.psi.ch.

[10] X. Maeder, J. Michler, (Xavier.Maeder@empa.ch), Empa, Thun: **HIGH-EF - Large grained, low stress multi-crystalline silicon thin film solar cells on glass by a novel combined diode laser and solid phase crystallization process** (Annual Report) http://www.empathun.ch.

[11] D. Brémaud, P. Blösch, D. Güttler, A.N. Tiwari, (Ayodhya.Tiwari@empa.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** (Annual Report) http://www.tfp.ethz.ch.

[12] A. N. Tiwari, C. Hibberd, Y.E. Romanyuk, (Ayodhya.Tiwari@empa.ch), ETH, Zürich: **Thin Film CIGS Solar Cells with a Novel Low Cost Process** (Annual Report) http://www.tfp.ethz.ch.

[13] D. Güttler, A. Chirila, Dr. A. N. Tiwari, (Ayodhya.Tiwari@empa.ch), ETH, Zürich: **LARCIS: Large-Area CIS Based Solar Modules for Highly Productive Manufacturing** (Annual Report) http://www.tfp.ethz.ch.

[14] D. Güttler, S. Bücheler, S. Seyrling, R. Verma, A. N. Tiwari, (Ayodhya.Tiwari@empa.ch), ETH, Zürich: **ATHLET: Advanced Thin-Film Technologies for Cost Effective Photovoltaics** (Annual Report) http://www.hmi.de/projects/athlet/ / http://www.tfp.ethz.ch.

[15] A. N. Tiwari, (Ayodhya.Tiwari@empa.ch), ETH, Zürich: **Laser patterning of Cu(In,Ga)Se_2 solar cells on flexible foils for monolithic integration** (Annual Report) http://www.tfp.ethz.ch.

[16] R. Kern, M. Kaelin, (marc.kaelin@flisom.ch), Flisom, Zürich: **Development of flexible CIGS Solar Modules with metal Grids** (Annual Report) http://www.flisom.ch.

[17] R. Thampi, (ravindranathan.thampi@epfl.ch), EPFL - ISIC, Lausanne: **ROBUST DC: Efficient and Robust Dye Sensitzed Solar Cells and Modules** (Annual Report) http://isic.epfl.ch.

[18] [1] J.O. Schumacher, [1] M. Schmid, [2] G. Rothenberger, [2] S. Wenger, (juergen.schumacher@zhaw.ch), [1] Zürcher Hochschule für Angewandte Wissenschaften ZHAW - ICP, Winterthur [2] EPFL - LPI, Lausanne: **ModSol: Modeling, simulation and loss analysis of dye-sensitized solar cells** (Annual Report) http://www.zhaw.ch.

[19] R. Hany, F.A. Castro, F. Nüesch, J. Heier, (roland.hany@empa.ch), EMPA, Dübendorf: **Organic photovoltaic devices** (Annual Report) http://www.empa.ch.

[20] F. Nüesch, (frank.nueesch@empa.ch), EMPA, Dübendorf: **HIOS-Cell** http://www.empa.ch.

[21] F. Nüesch, (frank.nueesch@empa.ch), EMPA, Dübendorf: **Transparent and Flexible Solar Cell Electrodes made from Precision Fabric** http://www.empa.ch.

[22] [1] B. Ruhstaller, [1] R. Häusermann, [1] N. A. Reinke, [2] C. Winnewisser, [2] T. Offermans, [3] M. Turbiez, [3] M. Düggeli, [4] R. Janssen, [5] J. Bisquert, (beat.ruhstaller@zhaw.ch), [1] ZHAW, Winterthur, [2] CSEM, Basel, [3] Ciba Inc., Basel, [4] TU Eindhoven, Netherlands, [5] Universitat Jaume I, Spain: **Apollo: Efficient areal organic solar cells via printing** (Annual Report).

[23] T. Meyer, (toby@solaronix.com), Solaronix, Aubonne: **OrgaPvNet: Coordination Action towards stable and low-cost organic solar cell technologies and their application** (Annual Report) http://www.solaronix.com.

[24] T. Meyer, A. Meyer, (toby@solaronix.com), Solaronix, Aubonne: **NAPOLYDE: Nano structured polymer deposition processes for mass production of innovative systems for energy production & control and for smart devices** (Annual Report) http://www.solaronix.com.

[25] T. Meyer, A. Meyer, (toby@solaronix.com), Solaronix, Aubonne: **FULLSPECTRUM: A new PV wave making more efficient use of the solar spectrum** (Annual Report) http://www.fullspectrum-eu.org / www.solaronix.com.

[26] D. Brühwiler, (bruehwi@aci.uzh.ch), ACI - University of Zurich, Zürich: **Development of efficient luminescent concentrators based on inorganic/organic nanomaterials for applications in solar energy conversion** (Annual Report) http://www.aci.uzh.ch.

[27] F. Nüesch, (frank.nueesch@empa.ch), EMPA, Dübendorf: **ThinPV - Cost efficient thin film photovoltaics for future electricity generation** (Annual Report) http://www.empa.ch.

[28] M. Spirig, (info@solarenergy.ch), Institut für Solartechnik SPF, Rapperswil: **PECNet: Aufbau eines Schweizer Kompetenznetzwerks für die Solare Wasserspaltung mittels hybrider PV-PEC Zellen** (Annual Report, Final Report Projekt 101883) http://www.solarenergy.ch.

[29] T. Szacsvay, (sz@3-s.ch), 3S, Lyss: **BIPV-CIS- Improved integration of PV into existing buildings by using thin film modules for retrofit** (Final Report) http://www.3-s.ch.

[30] T. Szacsvay, (sz@3-s.ch), 3S, Lyss: **Smarttile: Innovative Photovoltaik-Indachlösung** (Annual Report) http://www.3-s.ch.

[31] Y. Leterrier, J. Rion, L. Lalande, P. Liska, A. Vasilopoulos, (yves.leterrier@epfl.ch), EPFL - LTC, Lausanne: **Ultralight Photovoltaic Structures** (Annual Report, Final Report) http://ltc.epfl.ch.

[32] D. Chianese, N. Cereghetti, A. Realini, G. Friesen, E. Burà, I. Pola, T. Friesen, R. Rudel (domenico.chianese@supsi.ch), SUPSI, DACD, ISAAC-TISO, Canobbio: **Centrale di test ISAAC-TISO: Qualità e resa energetica di moduli fotovoltaici** (Annual Report) http://www.isaac.supsi.ch.

[33] G. Friesen, I. Pola, T. Friesen, K. Nagel, F. Morini, A. Jimenez, (gabi.friesen@supsi.ch), SUPSI, DACD, ISAAC-TISO, Canobbio: **PERFORMANCE - ISAAC Activities** (Annual Report) http://www.pv-performance.org / www.isaac.supsi.ch.

[34] R. Rudel, D. Chianese (domenico.chianese@supsi.ch), SUPSI, DACD, ISAAC-TISO, Canobbio: **Lifetime, mechanical and security testing for PV module certification** http://www.isaac.supsi.ch.

[35] H. Häberlin, L. Borgna, D. Gfeller, M. Kämpfer, M. Münger, Ph. Schärf, U. Zwahlen, (heinrich.haeberlin@bfh.ch), Berner Fachhochschule, Technik und Informatik, Burgdorf: **Photovoltaik Systemtechnik 2007-2010 (PVSYSTE 07-10)** (Annual Report) http://www.pvtest.ch.

[36] P. Gaillard, (pgaillard@maxwell.com), Maxwell Technologies, Rossens: **SoS-PVi: Security of Supply Photovoltaic Inverter** (Annual Report, Final Report) http://www.maxwell.com.

[37] W. Durisch, (wilhelm.durisch@psi.ch) PSI, Villigen: **FULLSPECTRUM: A new PV wave making more efficient use of the solar spectrum**(Final Report) http://www.fullspectrum-eu.org / http://www.psi.ch.

[38] A. Borschberg, (andre.borschberg@solarimpulse.com), Solar Impulse, Lausanne: **Solarimpulse** http://www.solar-impulse.com.

[39] R. Domjan, (info@planetsolar.org), PlanetSolar, Yverdon-les-Bains: **PlanetSolar** http://www.planetsolar.org.

[40] P. Hüsser, (pius.huesser@novaenergie.ch), Nova Energie, Aarau: **Schweizer Beitrag zum IEA PVPS Programm - Task 1** (Annual Report) www.iea-pvps.org / http://www.novaenergie.ch.

[41] Th. Nordmann, L. Clavadetscher, (nordmann@tnc.ch), TNC Consulting, Erlenbach: **IEA PVPS Programm Task 2 Schweizer Beitrag 2008** (Annual Report) http://www.tnc.ch.

[42] S. Nowak, M. Ndoh Rossier, C. Spörndli, (info@repic.ch), NET, St. Ursen: **REPIC: Swiss Interdepartmental Platform for Renewable Energy and Energy Efficiency Promotion in International Cooperation** (Annual Report) http://www.repic.ch

[43] P. Renaud, L. Perret, (pierre.renaud@planair.ch), Planair, La Sagne: **IEA PVPS Task 10 – Swiss contribution** (Annual Report) http://www.planair.ch.

[44] M. Ryser, (michel.ryser@solarmax.com), Sputnik, Biel: **IEA PVPS Task 11 : Hybride Photovoltaik Systemen in Mininetzen.**

[45] R. Frischknecht, M. Stucki (frischknecht@esu-services.ch), ESU-services, Uster*:* **IEA PVPS Task 12: Swiss activities in 2008 - Aktualisierung der Ökobilanz von CdTe - PV** (Annual Report) http://www.esu-services.ch.

[46] J. Remund, (remund@meteotest.ch), Meteotest, Bern: **IEA SHC Task 36: Solar resource knowledge management** (Annual Report) http://www.meteotest.ch.

[47] P. Ineichen, (pierre.ineichen@unige.ch), UNIGE Groupe Energie, Genève: **Solar Resource Management, IEA Solar Heating & Cooling Programme, Task 36** http://www.unige.ch/energie/.

[48] P. Toggweiler, T. Hostettler, (peter.toggweiler@enecolo.ch), Swissolar, Zürich: **Normierung für PV-Systeme** (Annual Report) http://www.swissolar.ch / http://www.enecolo.ch.

[49] [1] S. Nowak, [1] M. Gutschner, [1] S. Gnos; [2] S. Oberholzer, (stefan.nowak@netenergy.ch), [1] NET, St. Ursen, [2] BFE, Ittigen: **PV-ERA-NET: Networking and Integration of National and Regional Programmes in the Field of Photovoltaic (PV) Solar Energy Research and Technological Development (RTD) in the European Research Area (ERA)** (Annual Report) http://www.pv-era.net / http://www.netenergy.ch.

8. List of P+D Projects

Annual Report 2008 available
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.

[50] Th. Nordmann, (nordmann@tnc.ch), TNC Consulting, Erlenbach: ***Bifaciale Photovoltaik-Lärmschutzanlage*** http://www.tnc.ch.

[51] D. Chianese, (domenico.chianese@supsi.ch), SUPSI, DACD, ISAAC-TISO, Canobbio: **Degradations- und Annealing-verhalten von Modulen mit amorphen Zellen** (Annual Report) http://www.isaac.supsi.ch.

[52] Th. Böhni, (boehni@euu.ch), Böhni Energie und Umwelt, Frauenfeld: **Nullenergieschulhaus Heilpädagogisches Zentrum Ekkharthof Kreuzlingen** (Annual Report) http://www.euu.ch.

[53] P. Toggweiler, (info@enecolo.ch), Enecolo, Mönchaltorf: **Praxistest Backup Wechselrichter** (Annual Report) http://www.solarstrom.ch.

[54] P. Goulpié, (pascal.goulpie@flexcell.com), VHF-Technologies, Yverdon, **Toiture expérimentale 2kW Flexcell** (Annual Report) http://www.flexcell.ch.

[55] Th. Hostettler (Hostettler_Engineering@Compuserve.com), Ingenieurbüro Hostettler, Bern: **Messkampagne Wittigkofen**

[56] Th. Hostettler (Hostettler_Engineering@Compuserve.com), Ingenieurbüro Hostettler, Bern: **Photovoltaic Energy Statistics of Switzerland 2007** (Annual Report).

[57] Ch. Meier, (info@energieburo.ch), Energiebüro, Zürich: **Preparation and Realisation of the Test- and Pilot Installation SOLIGHT** (Final Report Projekt 100116) http://www.energieburo.ch.

[58] P. Toggweiler, (info@enecolo.ch) , Enecolo, Mönchaltorf: **Dachintegration mit amorphen Dünnschichtzellen Turnhalle Wiesendangen** (Final Report Projekt 101788) http://www.solarstrom.ch.

9. References

[61] **Konzept der Energieforschung des Bundes 2008 bis 2011**, Eidgenössische Energieforschungskommission CORE, 2007, http://www.energieforschung.ch.

[62] **Konzept des Energieforschungsprogramm Photovoltaik für die Jahre 2008 - 2011**, Bundesamt für Energie, 2008, http://www.photovoltaic.ch.

[63] **http://www.pv-era.net.**

[64] **A Look Inside Solar Cells**, Workshop 16. - 18. November 2008 in Ascona, Organisation: F. Nüesch, (frank.nueesch@empa.ch), EMPA, Dübendorf, http://www.empa.ch/scw.

[65] **Current state-of-the art and best practices of BiPV,** http://www.pv-performance.org.

[66] **Regulations and building codes for BiPV systems in Europe,** September 2008, http://www.pv-performance.org.

[67] **Actual temperatures of building integrated PV modules,** September 2008, http://www.pv-performance.org.

[68] **Annual Report 2008**, IEA PVPS, 2009, http://www.iea-pvps.org.

[69] **National Survey Report on PV Power Applications in Switzerland 2007**, P. Hüsser, (pius.huesser@novaenergie.ch), Nova Energie, August 2008.

[70] **Trends in Photovoltaic Applications in selected IEA countries between 1992 and 2007**, IEA PVPS Task T1-17:2008, http://www.iea-pvps.org.

[71] **Nachhaltigkeitsstudie – Solarenergie 2008 – Stürmische Zeiten vor dem nächsten Hoch**, M. Fawer-Wasser (matthias.fawer@sarasin.ch), Sarasin, November 2008.

[72] **MIT Future of Solar Energy Study,** Executive Director: Joshua Linn (jlinn@mit.edu), Massachusetts Institute of Technology (MIT), Cambridge MA USA.

[73] **Solar PV Development Strategies in Europe, 2008–2020,** Thomas Gregory (tgregory@emerging-energy.com), Emerging Energy Research, Cambridge MA USA, http://www.emerging-energy.com, June 2008.

[74] **Photovoltaic Energy Generation,** General Secretary: Thomas P. Pearsall, (Pearsall@epic-assoc.com), EPIC, Paris http://www.epic-assoc.com.

[75] **IEA PVPS Newsletter**, zu beziehen bei Nova Energie, Schachenallee 29, 5000 Aarau, Fax 062 834 03 23, (pius.huesser@novaenergie.ch).

[76] **http://www.iea-pvps.org**.

[77] **Performance Database**, IEA PVPS Task 2, May 2007, download: http://www.iea-pvps-task2.org

[78] **http://www.repic.ch**.

[79] **Renewable Energy Services for Developing Countries - In Support of the Millennium Development Goals: Recommended Practice & Key Lessons**, IEA PVPS Task 9-09-2008, February 2008, http://www.iea-pvps.org.

[80] **http://www.pvupscale.org**.

[81] **Country Specific Added Value Analysis of PV Systems,** IEA PVPS Task 10-02-2008, January 2008, http://www.iea-pvps.org / http://www.iea-pvps-task10.org.

[82] **Urban BIPV in the New Residential Construction Industry,** IEA PVPS Task 10-03-2008, January 2008, http://www.iea-pvps.org / http://www.iea-pvps-task10.org.

[83] **Examples of community-scale PV installation in urban area: PV community database,** IEA PVPS Task 10-04-2008, January 2008, http://www.iea-pvps.org / http://www.iea-pvps-task10.org.

[84] **Visual Tool for Photovoltaics Operating on Electric Grids,** 2008, http://www.iea-pvps-task10.org.

[85] **IEA PVPS Educational Tool: Building Integrated PV Educational Tool,** http://www.bipvtool.com.

[86] **Study on the development of a take back and recovery system for photovoltaic products,** K. Sander, (sander@oekopol.de), Ökopol, November 2007**,** http://www.pvcycle.org.

[87] **IEC 61646** (2008-05) Ed. 2.0 Bilingual English and French: Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval http://www.iec.ch.

[88] **IEC 62116** (2008-09) Ed. 1.0 Bilingual English and French: Test procedure of islanding prevention measures for utility-interconnected photovoltaic inverters http://www.iec.ch.

[89] **IEC/TS 62257-7** (2008-04) Ed. 1.0 English: Recommendations for small renewable energy and hybrid systems for rural electrification - Part 7: Generators http://www.iec.ch.

[90] **IEC/TS 62257-7-3** (2008-04) Ed. 1.0 English: Recommendations for small renewable energy and hybrid systems for rural electrification - Part 7-3: Generator set - Selection of generator sets for rural electrification systems http://www.iec.ch.

[91] **IEC/TS 62257-9-1** (2008-09) Ed. 1.0 English: Recommendations for small renewable energy and hybrid systems for rural electrification - Part 9-1: Micropower systems http://www.iec.ch.

[92] **IEC/TS 62257-9-6** (2008-09) Ed. 1.0 English: Recommendations for small renewable energy and hybrid systems for rural electrification - Part 9-6: Integrated system - Selection of Photovoltaic Individual Electrification Systems (PV-IES) http://www.iec.ch.

[93] **IEC 60904-7** (2008-11) Ed. 3.0 Bilingual English and French: Photovoltaic devices - Part 7: Computation of the spectral mismatch correction for measurements of photovoltaic devices http://www.iec.ch.

[94] **IEC 60904-3** (2008-04) Ed. 2.0 Bilingual English and French: Photovoltaic devices - Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data http://www.iec.ch.

[95] **Schweizer Nationalkomitee - Technische Fachkommission TK 82,** Kontakt: Electrosuisse, Ansprechpartner des TK 82, Eliane Andenmatten (eliane.andenmatten@electrosuisse.ch, 044 956 11 11), Vorsitzenden des TK 82, Herrn Peter Toggweiler (Peter.Toggweiler@enecolo.ch, 044 994 90 01).

[96] **http://ec.europa.eu/research/fp6/index_en.cfm?p=9_eranet**.

[97] **Strategic Research Agenda for Photovoltaic Solar Energy Technology,** The European Photovoltaic Technology Platform, 2007, http://www.eupvplatform.org/fileadmin/Documents/PVPT_SRA_Complete_070604.pdf.

[98] **http://www.eupvplatform.org**.

[99] **European Strategic Energy Technology Plan (SET Plan),** http://ec.europa.eu/energy/technology/set_plan/set_plan_en.htm.

[100] **Die 23rd European Photovoltaic Solar Energy Conference & Exhibition Valencia 01. - 05.09.2008 aus Schweizer Sicht**, zu beziehen bei der Programmleitung Photovoltaik, c/o NET, Waldweg 8, 1717 St. Ursen, info@netenergy.ch, http://www.photovoltaic.ch.

10. Further Information

Further information may be obtained from the programme management:

Dr. Stefan Nowak, NET Nowak Energy & Technology Ltd., Waldweg 8, 1717 St. Ursen, Switzerland
Tel. ++41 (0) 26 494 00 30, Fax ++41 (0) 26 494 00 34, email: stefan.nowak@netenergy.ch

Preparation of Summary Report: Manuela Schmied Brügger, Stephan Gnos,
NET Nowak Energy & Technology Ltd., info@netenergy.ch

Translation: Alan Hawkins, A.C. Hawkins Consulting & Services, 5018 Erlinsbach, Switzerland

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.hti.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

DACD	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
ICP	Institute of Computational Physics	http://www.icp.zhaw.ch
IEC	International Electrotechnical Commission	http://www.iec.ch
IMT	Institute of microtechnology University Neuchâtel	http://pvlab.epfl.ch
IMX	Institute of Materials	http://imx.epfl.ch
ISAAC	Institute for applied sustainability to the built environment	http://www.isaac.supsi.ch
ISIC	Institute of Chemical Sciences and Engineering	http://isic.epfl.ch
LPI	Laboratory of Photonics and Interfaces	http://isic.epfl.ch/lpi
LTC	Laboratory of Polymer and Composite Technology	http://ltc.epfl.ch
PSI	Paul Scherer Institute	http://www.psi.ch
SDC	Swiss Agency for Development and Cooperation	http://www.sdc.admin.ch
SECO	State Secretariat for Economic Affairs	http://www.seco.admin.ch
SER	State Secretariat for Education and Research	http://www.sbf.admin.ch
SESA	Swiss Electricity Supply Association	http://www.strom.ch
SFOE	Swiss Federal Office of Energy	http://www.sfoe.admin.ch
SPF	Institut für Solartechnik	http://www.solarenergy.ch
SUPSI	The University of Applied Sciences of Southern Switzerland	http://www.supsi.ch
ZHAW	Zurich University of Applied Sciences	http://www.zhaw.ch

International Organisations

EU (RTD)	European Union (RTD-Programme) Community Research & Development Information Service of the European Communities	http://www.cordis.lu
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 SolarPACES	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.energieforschung.ch
SNF	Swiss National Science Foundation	http://www.snf.ch
ETH-Rat	Board of the Swiss Federal Institutes of Technology	http://www.ethrat.ch
BFS	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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NEW PROCESSES AND DEVICE STRUCTURES FOR THE FABRICATION OF HIGH EFFICIENCY THIN FILM SILICON PHOTOVOLTAIC MODULES

Annual Report 2008

Author and Co-Authors	C. Ballif, A. Feltrin, F. Sculatti-Meillaud, S. Fay, F.J. Haug, V. Terrazzoni-Daudrix, R. Theron, R. Tscharner
Institution / Company	Institute of Microtechnology / University of Neuchâtel
Address	Rue A.L. Breguet 2, 2000 Neuchâtel
Telephone, E-mail, Homepage	+41 32 718 33 30, +41 32 718 32 01, christophe.ballif@epfl.ch http://www.unine.ch/pv
Project- / Contract Number	OFEN 101191 / 153032
Duration of the Project (from – to)	1.12.2007 - 31.12.2011
Date	10.12.2008

ABSTRACT

The global project goal is to allow for a lowering of the cost of solar electricity based on thin film silicon. In particular, this "technology push" project aims at developing the processes and device structure for the future generation of thin film silicon modules, based on amorphous Si or SiGe alloys, and microcrystalline silicon. The major project axes consider work on layers with new or better properties (e.g. new materials with higher transparency), on improved processes (more stable, faster processes, yielding higher quality layers, with potential lower production costs), on enhanced cells and modules reliability, leading to increased device and module efficiencies while ensuring low costs and reliability.

The key results of this first year of the project can be summarised as follow:

- Intermediate reflector based on SiOx materials with low refractive index (n=1.7) were realised and could be introduced in high efficiency micromorph cells (13.1% initial efficiency on 1 cm^2).
- Cells with ZnO deposited in chemical vapour phase (CVD) could be made virtually stable to damp heat (85°, 85% humidity) without encapsulation.
- Microcrystalline cells with efficiency >7.1% could be fabricated in large areas reactor with deposition rates as high as 1 nm/s.
- New asymmetric intermediate reflectors were designed and implemented in n-i-p micromorph cells compatible with cells on plastic design. Stabilised efficiency of 10.1% could be achieved.
- Processes for high efficiency tandems a-Si/a-Si on glass were developed and stabilised efficiency of 8.3% could be reached.
- All key steps for embedding of IMT's cells and modules were tested and characterised.

Finally an important effort was made in terms of equipment and infrastructure upgrade, with the design and/or acquisition of new state-of-the-art research tools (cluster PECVD systems, sputtering, lasering, ellipsometry). These tools will be used in the next part of the project.

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

Annual Report 2008

Author and Co-Authors	F.-J. Haug
Institution / Company	Institute of Microtechnology / University of Neuchâtel
Address	Rue A.L. Breguet 2, 2000 Neuchâtel
Telephone, E-mail, Homepage	+41 (0)32 718 33 25, franz-josef.haug@epfl.ch
Project- / Contract Number	CTI 8809.2
Duration of the Project (from – to)	01.09.2007 - 31.08.2009
Date	04.12.2008

ABSTRACT

The CTI project 8809.2 is a collaboration between two partners, the company *VHF Technologies, Yverdon*, and the *PV-Lab at the Institute of Microtechnology, Neuchâtel (IMT)*. The main points of the project are the development of a dielectric back reflector, a texturing process for the substrate, and the development of tandem processes using two stacked amorphous absorber layers which can yield higher stability against light induced degradation of the cells and lower interconnection losses. During 2008 the project was running closely to the anticipated schedule.

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HIGH EFFICIENCY THIN-FILM PASSIVATED SILICON SOLAR CELLS AND MODULES

THIFIC: THIN FILM ON CRYSTALLINE SI

Annual Report 2008

Author and Co-Authors	S. De Wolf, S. Olibet, J. Damon-Lacoste, L. Fesquet, C. Ballif
Institution / Company	Institute of Microtechnology (IMT) / University of Neuchâtel
Address	Rue A.L. Breguet 2, 2000 Neuchâtel
Telephone, E-mail, Homepage	+41 (0) 32 718 33 78, stefaan.dewolf@epfl.ch, www.unine.ch/pv
Project- / Contract Number	Axpo Naturstrom-fonds 0703
Duration of the Project (from – to)	01.06.2007 - 31.05.2011
Date	08.12.2008

ABSTRACT

THIFIC (Thin film on crystalline Si) is a 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 fully processed at low temperature (typically below 200°C) and may 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. The launch of this Axpo Naturstrom-Fonds project was based on these results, which were achieved in a short time. Meanwhile, based on single process step analysis, a better physical understanding of interface phenomena occurring in silicon heterojunction solar cells has been obtained. A crucial issue is that the *a*-Si:H / *c*-Si interface should be atomically sharp. The precise crystal orientation of the wafers plays in this a role, and hence also the surface texture (which allows better light trapping). Previously, well cleaned alkaline textured crystalline silicon surfaces could be obtained. Now we achieved crucial insight in how to avoid epitaxial growth on such surfaces, allowing the fabrication of high quality a-Si:H/c-Si textured interfaces. By this, we have demonstrated an open-circuit voltage of 700 millivolt, also on textured surfaces.

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HETSI: HETEROJUNCTION SOLAR CELLS BASED ON A-SI / C-SI

Annual Report 2008

Author and Co-Authors	S. De Wolf, J. Damon-Lacoste, L. Fesquet, S. Olibet C. Ballif
Institution / Company	Institute of Microtechnology (IMT) / University of Neuchâtel
Address	Rue A.L. Breguet 2, 2000 Neuchâtel
Telephone, E-mail, Homepage	+41 (0)32 718 33 78, stefaan.dewolf@epfl.ch, www.unine.ch/pv
Project- / Contract Number	HETSI Grant agreement no.: 211821
Duration of the Project (from – to)	01.02.2008 - 01.02.2011
Date	08.12.2008

ABSTRACT

Hetsi (Heterojunction solar cells based on a-Si:H / c-Si) is a project sponsored by the European Commision. This project links, for the first time, world class EU companies and institutes with experience in the fields of both crystalline Si and thin film silicon. Its short term target is to demonstrate in Europe the industrial feasibility of heterojunction solar cells, by depositing very thin film silicon layers (typically 5-10 nanometers of amorphous and/or microcrystalline silicon) on top of silicon wafers. Based on ultra thin silicon wafers (100-150 µm, n-type silicon, 5-6 g /W, 125mm PS monocrystalline and 156*156mm^2 multicrystalline), with very high efficiencies : 21 % for mono and 18 % on multi at the cell level, 20 % at the module level for mono and 17 % at the module level for multi, this should result in a 50% cost reduction compared to mainline production technology. The medium term target is to demonstrate the concept of ultra-high efficiency rear-contact cells based on a-Si:H/c-Si heterojunction (RCC-HET > 22% efficiency).

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. Meanwhile, based on single process step analysis, a better physical understanding of interface phenomena occurring in silicon heterojunction solar cells has been obtained. A crucial issue is that the *a*-Si:H / *c*-Si interface should be atomically sharp. For this type of interfaces, it has been shown that annealing at low temperatures may improve the passivation quality tremendously. The detrimental influence of epitaxial growth, verified with spectroscopic ellipsometry, on the passivation properties has also been confirmed. Finally, in an effort to upscale the processes, a new in-house built, large area and automated deposition system has been taken into use: the usable deposition area is 410 mm × 520 mm with RF-frequency of 40 MHz. The obtained results should open the way to very high efficiency heterojunction solar cell fabrication in large area reactors.

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

Annual Report 2008

Author and Co-Authors	V. Terrazzoni, F-J. Haug, C. Ballif
Institution / Company	Institute of Microtechnology (IMT) / University of Neuchâtel
Address	Rue A.L. Breguet 2, 2000 Neuchâtel
Telephone, E-mail, Homepage	+41 32 718 33 30, vanessa.terrazzoni@epfl.ch / www.unine.ch/flex
Project- / Contract Number	SES-CT-019948
Duration of the Project (from – to)	01.10.2005 - 30.09.2008
Date	10.12.2008

ABSTRACT

FLEXCELLENCE (www.unine.ch/flex) was a European project (STREP) financed under the 6th framework program, which started on October 1st 2005 and ended 3 years later in September 2008. IMT acted as a coordinator.

The goal of the project was to develop the equipment and the processes for cost-effective roll-to-roll production of high-efficiency thin-film modules involving amorphous (a-Si:H) and microcrystalline silicon (µc-Si:H).

Eight partners, with extended experience in the complementary fields of cells and processing, modules and interconnections, production, machinery and reliability were involved in this project, with IMT as coordinator.

Globally, the project allowed significant progresses, both at the level of deposition process developpements, substrate preparation, equipment hardware and reliability testing, which are described in several publications and reports of the various parties involved.

During the last year of the project, IMT was mainly involved in the development and optimisation of single a-Si:H and µc-Si:H cells as well as of tandem micromorph cells on plastic substrates. By adapting a special kind or intermediate reflectors for cells deposited on nano-structured plastic foils, a stabilised micromorph cell efficiency up to 9.8% on plastic could be achieved.

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ATHLET - ADVANCED THIN FILM TECHNOLOGIES FOR COST EFFECTIVE PHOTOVOLTAICS

Annual Report 2008

Author and Co-Authors	N. Wyrsch, C. Ballif
Institution / Company	Institute of Microtechnology (IMT) / University of Neuchâtel
Address	Rue A.L. Breguet 2, 2000 Neuchâtel
Telephone, E-mail, Homepage	+41 (0) 32 718 33 57, nicolas.wyrsch@epfl.ch, www.unine.ch/pv
Project- / Contract Number	ATHLET / IP 019670
Duration of the Project (from – to)	01.01.2006 – 31.12.2009
Date	10.12.2008

ABSTRACT

ATHLET (Advanced Thin Film Technologies for Cost Effective Photovoltaics) is a 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 Solar* 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 develop 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 third year, IMT work within Athlet was split on the further development of micromorph tandem on small area and on the development of micromorph tandem cell components in an industrial KAI-S and KAI-M reactors. Concerning the latter, a second chamber was put in operation on our double chamber system and several plasma diagnostics were implemented. The work on small area focused mainly on the improvement of the light management in the micromorph tandem, by introducing anti reflection layers and optimizing the component cells and SiO_x based intermediate layer thicknesses. The initial efficiency was increased to a remarkable 13.3%. Further work needs to be done to also gain in stable efficiency. In the KAI-M system, on large area, micromorph devices deposited at 1 nm/s could be fabricated with initial efficiency close to 11% and stable efficiency of 9.4%. Process for the deposition of SiO_x based intermediate layer was also transferred to KAI-M for the further improvement of micromorph devices.

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ZWEIDIMENSIONALE NANOSTRUKTUREN FÜR SILIZIUM-SOLARZELLEN

Annual Report 2008

Author and Co-Authors	D. Gablinger, R. Morf
Institution / Company	Paul Scherrer Institut PSI
Address	5232 Villigen PSI
Telephone, E-mail, Homepage	+41 (0) 56 310 53 28, david.gablinger@psi.ch, http://www.psi.ch
Project- / Contract Number	102807 / 153611
Duration of the Project (from – to)	2008 - 2011
Date	02.12.2008

ABSTRACT

The main goal of the project is the development of **efficient numerical methods** to solve the Maxwell equations in order to calculate the optical properties of two-dimensional periodic grating structures rigorously.

The structures shall be optimized for **broad-band absorption of both polarizations in thin films**. This optimization should take into account the experimental requirements and limitations. Prototype structures will be fabricated with e-beam lithography by the Laboratory for Micro- and Nanotechnology at PSI, while experimental characterisation of the structures, as well as prototype solar cell fabrication will be done by the Institute of Microtechnology in Neuchâtel.

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HIGH-EF - LARGE GRAINED, LOW STRESS MULTI-CRYSTALLINE SILICON THIN FILM SOLAR CELLS ON GLASS BY A NOVEL COMBINED DIODE LASER AND SOLID PHASE CRYSTALLIZATION PROCESS

Annual Report 2008

Author and Co-Authors	X. Maeder, J. Michler
Institution / Company	Empa – Materials Science and Technology
Address	Feuerwerkerstr. 39, CH-3602 Thun, Switzerland
Telephone, E-mail, Homepage	+41 (0) 33 228 29 59, Xavier.Maeder@empa.ch, www.empa.ch
Project- / Contract Number	EU FP7 Grant Agreement Num. 213303
Duration of the Project (from – to)	01.01.2008 - 31.12.2010
Date	13.01.2009

ABSTRACT

The objective of the High-ef project is to provide the silicon thin film photovoltaic (PV) industry with a process allowing high solar cell efficiencies (>10%) by large grains in the material at competitive production cost. The process is based on a combination of laser melt-mediated crystallization of an amorphous silicon (a-Si) seed layer (<500nm thickness) and epitaxial thickening (to > 2μm) of the seed layer by solid phase epitaxy (SPE) process. The combined laser –SPE process represents a major break-through in silicon thin film photovoltaic on glass as it substantially enhances the grain size and reduces the defect density and the stress levels compared to e.g. standard solid phase crystallisation processes (SPC) on glass which provides grains less than 10μm in diameter with a high density of internal extended defects. A low cost laser processing will be developed in High-ef using highly efficient laser diodes with a wide line focus for the crystallisation of a large module area within one scan. The main tasks of Empa in the project are i) grains size, grain boundaries, texture and lattice defects characterizations of the Si thin film by electron backscatter diffraction techniques (EBSD), ii) elastic strains et residual stresses measurements by EBSD and iii) mechanical testing of the material.

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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 2008

Author and Co-Authors	D. Brémaud, P. Blösch, D. Güttler, A.N. Tiwari
Institution / Company	ETH Zurich
Address	Thin Film Physics Group, ETH, Technoparkstr. 1, 8005 Zürich
Telephone, E-mail, Homepage	+41 (0) 44 633 79 49, Ayodhya.Tiwari@empa.ch, http://www.tfp.ethz.ch
Project- / Contract Number	100964 / 152404
Duration of the Project (from – to)	01.12.2006 – 28.02.2009
Date	08.12.2008

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 shall be grown on in-line moving substrates. Our CIGS and customised CdS deposition equipments have been developed 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 are being optimised towards the development of high efficiency flexible solar cells with all in-line.

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 25 cm. Further the chemical bath deposition equipment for CdS layer was redesigned for large area substrates and optimized for minimal waste products.

Alternative electrical back contacts to conventional Mo are developed on flexible polyimide foils. Preferred materials are transparent conducting oxides (ITO) and metal-nitrides covered with a thin buffer layer facilitating tunneling of carriers across the CIGS-back contact interface. The deposition processes have been developed and properties of layers and interfaces have been investigated. Flexible solar cells of 12% have been achieved where both, the front and back electrical contacts are based on transparent conducting oxide layers.

In order to overcome the well known problems of the conventional Mo back contact efforts were made to employ Ti/TiN as an alternative back contact because of several attractive features of this system. The R&D work for feasibility study was performed in collaboration with two companies in Switzerland. Preliminary results have shown very much encouraging results as a flexible CIGS solar cell with high efficiency of 13.1% has been achieved with an alternative stacked back contact that offers several advantages for manufacturing as well as for long term performance stability of flexible solar cells.

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THIN FILM CIGS SOLAR CELLS WITH A NOVEL LOW COST PROCESS

Annual Report 2008

Author and Co-Authors	A. N. Tiwari, C.Hibberd, Y.E. Romanyuk
Institution / Company	ETH Zürich
Address	Thin Film Physics Group, Technoparkstr. 1, 8005 Zürich
Telephone, E-mail, Homepage	+41 (0) 44 633 79 49, Ayodhya.Tiwari@empa.ch, http://www.tfp.ethz.ch
Project- / Contract Number	100964 / 152223
Duration of the Project (from – to)	01.11.2006 - 31.10.2008
Date	12.12.2008

ABSTRACT

A chemical process for incorporating copper into indium gallium selenide layers has been developed with the goal of creating a precursor structure for the formation of copper indium gallium diselenide (CIGS) photovoltaic absorbers. Stylus profilometry, EDX, Raman spectroscopy, XRD and SIMS measurements show that when indium gallium selenide layers are immersed in a hot copper chloride solution in ethylene glycole, copper is incorporated as copper selenide with no increase in the thickness of the layers. The ion-exchange process in organic medium is advantageous over the aqua solution technique, which was investigated in 2007, because no corrosion of the metal back contact is observed, and it is possible to achieve sufficient Cu incorporation in thicker $(In,Ga)_2Se_3$ layers of 1.5-2 microns.

Further measurements show that annealing this precursor structure in the presence of selenium results in the formation of CIGS and that the supply of selenium during the annealing process has a strong effect on the morphology and preferred orientation of these layers. When the supply of Se during annealing begins only once the substrate temperature reaches ≈400°C, the resulting CIGS layers are smoother and have more pronounced preferred orientation than when Se is supplied throughout the entire annealing process.

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Bundesamt für Energie BFE

LARCIS - LARGE-AREA CIS BASED SOLAR MODULES FOR HIGHLY PRODUCTIVE MANUFACTURING

Annual Report 2008

Author and Co-Authors	D. Güttler, A. Chirila, Dr. A. N. Tiwari
Institution / Company	ETH Zürich
Address	Thin Film Physics Group, Technoparkstr. 1, 8005 Zürich
Telephone, E-mail, Homepage	+41 (0) 44 633 79 49, Ayodhya.Tiwari@empa.ch, http://www.tfp.ethz.ch
Project- / Contract Number	SES66-CT-2005-019757 / FP6-019757
Duration of the Project (from – to)	01.11.2005 – 31.10.2009
Date	15.12.2008

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 electro-deposition approaches are used for absorber deposition and other components of the solar cells are improved. Important objectives of the overall project are processing of CIGS modules by co-evaporation, application of cost-effective methods and development of alternative buffer and back contact layers for large area CIGS solar cells on glass substrates.

To meet the above-mentioned objectives the ETH group currently investigates i) the role of sodium incorporation into the CIGS absorber, as well as ii) different incorporation techniques in view of the suitability for the cost effective production. In order to improve the electronic properties of the CIGS absorber and thus enhance the cell efficiencies, first series of experiments were performed with the goal to determine the optimum dosage of sodium in the absorber material. Sodium fluoride layers of different thicknesses were deposited on top of the CIGS absorber layer and subsequently annealed. The cell performances were compared with respect the so introduced Na-dosage. Based on these results different sodium incorporation methods were compared.

Another R&D activity of the ETH group is to modify the CIGS absorber in such a way that a separate deposition of the buffer layer between ZnO and CIGS could be avoided. First results were obtained by finishing the CIGS growth process with the deposition of an ~10 nm thick In_xSe_y surface layer. Encouraging results have been obtained, but so far the efficiencies are below the highest efficiencies achieved with CdS buffer layer. However, this technique is promising for a low cost, in-line applicable production, since this thin $InSe_X$ layer can be deposited directly after the growing of CIGS, without additional processing steps and material requirements.

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ATHLET - ADVANCED THIN FILM TECHNOLOGIES FOR COST EFFECTIVE PHOTOVOLTAICS

Annual Report 2008

Author and Co-Authors	D. Güttler, S. Bücheler, S. Seyrling, R. Verma, A. N. Tiwari
Institution / Company	ETH Zürich
Address	Thin Film Physics Group, ETH, Technoparkstr. 1, 8005 Zürich
Telephone, E-mail, Homepage	+41 (0) 44 633 79 49, Ayodhya.Tiwari@empa.ch, http://www.tfp.ethz.ch
Project- / Contract Number	ATHLET CIS / FP-2204-Energy-3
Duration of the Project (from – to)	01.01.2006 – 31.12.2009
Date	16.12.2008

ABSTRACT

The ATHLET project is an integrated project of the European Union involving 24 partners 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 ETH Group is participating in two work packages with the objective to investigate alternative buffer layers deposited by vacuum evaporation (PVD) and ultrasonic spray pyrolysis (USP), and the development of high efficiency CIGS solar cells on flexible substrates and for tandem solar cells.

A PVD method was developed at ETH to deposit In_2S_3 buffer layers on CIGS absorber and after a comprehensive work the process was optimised to achieve 14.1% efficiency solar cells on glass substrates. Further experiments were started to transfer the knowledge for flexible solar cells. Flexible CIGS solar cells of 10.1% efficiency were achieved with evaporated In_2S_3 buffer layer, while the reference flexible cell with chemical bath deposited buffer had 13.2% efficiency. This is the first report of CdS-free flexible CIGS solar cell on polymer with efficiency approaching 10%.

Detailed investigations on USP deposited In_2S_3 buffer layers were conducted to characterise the structural and optical properties and to understand the regimes of impurity phase formation and growth kinetics. 12.4% efficiency solar cells achieved with USP method show the promising potential of this low-cost, non-vacuum thin film deposition method.

In order to develop CIGS based tandem solar cells growth and properties of CIGS with different Ga concentration on Mo and ZnO:Al coated glass substrates were investigated. Unfortunately, solar cells with Ga rich composition exhibit rather low efficiency. However, the development 13.5% efficiency cell on ZnO:Al coated transparent conducting oxide substrate, achieved with 24% Ga content, is quite interesting for tandem solar cells as the efficiency value is comparable to the results on Mo coated glass substrates.

Research performed in Swiss national projects supported by BFE and CCEM had some synergies with the topics of the ATHLET project and they helped to achieve success in this EU project.

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LASER PATTERNING OF CU(IN,GA)SE_2 SOLAR CELLS ON FLEXIBLE FOILS FOR MONOLITHIC INTEGRATION

Annual Report 2008

Author and Co-Authors	Dr. A. N. Tiwari
Institution / Company	ETH Zürich
Address	Thin Film Physics Group, Technoparkstr. 1, 8005 Zürich
Telephone, E-mail, Homepage	+41 (0) 44 633 79 49, Ayodhya.Tiwari@empa.ch, http://www.tfp.ethz.ch
Project- / Contract Number	KTI 8697.2
Duration of the Project (from – to)	July 2007 - July 2009
Date	December 2008

ABSTRACT

The project aims for the development of Cu(In,Ga)Se_2 solar modules on flexible substrate materials. It focuses on the development of technology for monolithic electric series connection of single solar cells grown on in-line moving polymer foils. The challenges of high precision patterning of multilayers on polymer substrates shall be overcome by using a high-tech laser patterning system. The developed processes and hardware compass the manufacturing of prototypes of monolithically integrated solar modules on flexible polymer substrates and the proof of concept of an automated system that can be implemented in a roll-to-roll manufacturing plant for flexible thin-film solar modules.

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DEVELOPMENT OF FLEXIBLE CIGS SOLAR MODULES WITH METAL GRIDS

Annual Report 2008

Author and Co-Authors	R. Kern, M. Kaelin
Institution / Company	FLISOM AG
Address	Technoparkstr. 1, 8005 Zürich
Telephone, E-mail, Homepage	+41 (0) 44 633 79 68, marc.kaelin@flisom.ch, www.flisom.ch
Project- / Contract Number	sponsored by axpo Naturstrom Fonds
Duration of the Project (from – to)	January 2007 – August 2008
Date	December 2008

ABSTRACT

The project focused 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.

Various processing steps for the production of flexible CIGS solar modules with advantageous metal grid interconnection have been investigated. These steps include optimizing the back contact patterning, serial connection of single cells and the optimization of the metal grid design. The developed mathematical models were verified by manufacturing of mini-modules of various output voltages and sizes. With the experience gained during the project, grid structures with very narrow printed conduction lines in the range of 50-100 micro meters were achieved in order to avoid optical losses of the shielded cell area. Finally, the deposition technology was further developed to yield demonstrator modules with monolithic metal grid interconnection for improved current collection in the window layer.

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ROBUST DSC

EFFICIENT AND ROBUST DYE SENSITZED SOLAR CELLS AND MODULES

Annual Report 2008

Author and Co-Authors	M. Graetzel, F. Sauvage and S. M. Zakeeruddin
Institution / Company	EPFL, SB, ISIC, LPI
Address	Station 6, Ecublens 1015- Lausanne
Telephone, E-mail, Homepage	+41 (0) 21 693 31 12, michael.graetzel@epfl.ch, http://isic2.epfl.ch/page58671-en.html
Project- / Contract Number	ROBUST DSC, FP7-212792
Duration of the Project (from – to)	01.03.2008 - 28.02.2011
Date	March 2009

ABSTRACT

ROBUST DSC aims to develop materials and manufacturing procedures for Dye Sensitized Solar Cells (DSC) with long lifetime and increased module efficiencies (7% target). The project intends to accelerate the exploitation of the DSC technology in the energy supply market.

The approach focuses on the development of large area, robust, 7% efficient DSC modules using scalable, reproducible and commercially viable fabrication procedures. In parallel with this objective, more fundamental research, employing new materials and device configurations, will target increasing the efficiency of labscale devices to 14 %. Progress on labscale devices will be fed directly into module development. The approach is based on the use of innovative low-cost materials, scalable manufacturing techniques, predictive device models and in-and out-door lifetime testing. A sound and scientific understanding of the basic procedures to manufacture the cells and a thorough knowledge of the fundamental processes in the cell are important tools for our success.

The partnership consists of: two SMEs (3G solar and G24i) that are committed to large-scale production of DSC, one industry (Corning) that has proven experience on inorganic encapsulation of organic displays (TV's, computer screens), three research institutes (ECN, IVF, ISE) with expertise in the field of long-term testing, up-scaling and module fabrication and four academic partners, world leaders in both new materials and concepts, and in fundamental research on cell function and modeling (EPFL, IMPERIAL, ICIQ, UAM).

We anticipate that this project will result in the demonstration of a new scalable, low cost, photovoltaic technology. It will therefore form the basis of a potentially substantial business opportunity aiming at developing a new solar cell product with cost and payback characteristics strongly advantaged over existing technologies. This will benefit the entire European community in creating economically accessible solar technology and significant industrial activity by demonstrating viable production procedures for DSC.

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MODELING, SIMULATION AND LOSS ANALYSIS OF DYE-SENSITIZED SOLAR CELLS

Annual Report 2008

Author and Co-Authors	[1] J. O. Schumacher, [1] M. Schmid, [2] G. Rothenberger, [2] S. Wenger
Institution / Company	[1] Institute of Computational Physics (ICP), Zürcher Hochschule für Angewandte Wissenschaften (ZHAW); [2] Laboratoire de Photonique et Interfaces (LPI), Ecole Polytechnique fédérale de Lausanne (EPFL)
Address	[1] ICP, ZHAW, Postfach 805, CH-8401 Winterthur; [2] EPFL - SB - ISIC – LPI, Station 6, CH-1015 Lausanne
Telephone, E-mail, Homepage	+41 (0) 58 934 69 89, juergen.schumacher@zhaw.ch, http://www.zhaw.ch
Project- / Contract Number	GRS-064/07
Duration of the Project (from – to)	01.09.2008 - 30.09.2010
Date	08.12.2008

ABSTRACT

Dye-sensitized solar cells (DSC) are an innovative technology for the production of electricity from solar energy, which was invented in Switzerland. In DSCs the sun light is harvested by an organic dye, adsorbed on a highly porous structure of titanium-dioxide nano-particles. In contrast to conventional silicon solar cells, the production processes of DSCs are based on relatively simple and inexpensive techniques, like e.g. screen printing. In addition no cost-intensive, exhaustible raw materials are needed. Therefore, DSCs could contribute an essential part to an economic production of solar energy for the future. DSCs are particularly suited for the use in alternative front glass elements in buildings or for local power supplies (e.g. sensor systems, light sources, consumer electronics).

The goal of this project is to develop validated models for DSCs. Modeling of the coupled optical, electrical and electrochemical processes in the DSC allows us to analyze quantitatively the different loss mechanisms of the energy conversion in the solar cell. This is crucial to improve the efficiency of the DSCs and for the development of appropriate materials for commercial production of DSCs. The new DSC models will be implemented into accurate and efficient numerical algorithms and made accessible by a user-friendly software. The software is intended for the use by researchers at academic laboratories as well as developers working for potential DSC manufacturers.

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ORGANIC PHOTOVOLTAIC DEVICES

NANOSCALE STRUCTURING OF IONIC DYES IN THIN SEMICONDUCTING BLEND FILMS

Annual Report 2008

Author and Co-Authors	R. Hany, F.A. Castro, F. Nüesch, J. Heier
Institution / Company	Empa, Lab for Functional Polymers
Address	Überlandstr. 129, CH-8600 Dübendorf
Telephone, E-mail, Homepage	+41 (0) 44 823 40 84, roland.hany@empa.ch, www.empa.ch
Project- / Contract Number	
Duration of the Project (from – to)	2007 - 2010
Date	10.12.2008

ABSTRACT

The controlled fabrication of submicron phase-separated morphologies of semiconducting organic materials is attracting considerable interest, for example in emerging thin-film optoelectronic device applications. We use the phenomenon of liquid-liquid dewetting during spin coating to fabricate films of cyanine dye / PCBM blends in a variety of morphologies with tunable dimensions below 100 nm and a large-area interface. The structure formation mechanism proceeds via a transient bilayer, which further spinodally destabilizes because of long-range molecular interactions. We developed a thermodynamic model showing that electrostatic forces induced by the mobile cyanine counter ions act as destabilizing pressure. We study the quantitative aspect of the film rupture mechanism and will combine this unique patterning methodology with the concept of cyanine dye doping for the fabrication of efficient organic solar cells.

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APOLLO: EFFICIENT AREAL ORGANIC SOLAR CELLS VIA PRINTING

Annual Report 2008

Author and Co-Authors	[1] B. Ruhstaller, [1] R. Häusermann, [1] N. A. Reinke, [2] C. Winnewisser, [2] T. Offermans, [3] M. Turbiez, [3] M. Düggeli, [4] R. Janssen, [5] J. Bisquert
Institution / Company	[1] ZHAW, Winterthur [2] CSEM, Basel [3] Ciba Inc., Basel [4] TU Eindhoven, Netherlands [5] Universitat Jaume I, Spain
Address	[1] Wildbachstrasse 21, 8401 Winterthur [2] Mattenstrasse 22, 4058 Basel
Telephone, E-mail, Homepage	[1] +41 (0) 58 934 78 36, beat.ruhstaller@zhaw.ch
Project- / Contract Number	102738 / 153575
Duration of the Project (from – to)	1.11.2008 – 1.4.2011
Date	12.12.2008

ABSTRACT

This project aims to combine plastic electronics expertise in Europe for realizing organic solar cells for empowering printed electronics applications. Existing solar cell technologies cannot provide the potential attributes such as printability in ambient conditions, flexibility and low cost. These research topics carry high innovation potential and unique selling points for Europe. If successful they open up new markets for the European high-tech industry allowing for Europe to take a leading position in printed electronics and solar cells.

So far, the development of organic solar cells was to a large extent a semi-empirical trial-and-error process, in which organic semiconducting materials were selected on the basis of their known or partially known separate properties. It has recently become clear that this provides an insufficiently sound basis for a further development. For further progress, an interdisciplinary approach with new materials, device concepts, models and characterization methods is critical.

The focus of this project is on single cells and tandem cells with record efficiency that feature ease of production and proof-of-principle for the interdisciplinary research approach. The detailed understanding of device operation allows for steady improvements in efficiency.

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ORGAPVNET

COORDINATION ACTION TOWARDS STABLE AND LOW-COST ORGANIC SOLAR CELL TECHNOLOGIES AND THEIR APPLICATION

Annual Report 2008

Author and Co-Authors	Dr. Toby Meyer
Institution / Company	Solaronix SA
Address	Ouriette 129 CH-1170 Aubonne
Telephone, E-mail, Homepage	+41 (0) 21 821 22 80, toby@solaronix.com, www.solaronix.com
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 2008

Author and Co-Authors	Dr. Toby Meyer & Andreas Meyer
Institution / Company	Solaronix SA
Address	Ouriette 129 CH-1170 Aubonne
Telephone, E-mail, Homepage	+41 (0) 21 821 22 80, toby@solaronix.com, www.solaronix.com
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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FULLSPECTRUM

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

Annual Report 2008

Author and Co-Authors	Dr. Toby Meyer & Andreas Meyer
Institution / Company	Solaronix SA
Address	Ouriette 129 CH-1170 Aubonne
Telephone, E-mail, Homepage	+41 (0) 21 821 22 80, toby@solaronix.com, www.solaronix.com
Project- / Contract Number	SES6-CT-2003-502620 / SER N° 03.0111-2
Duration of the Project (from – to)	01.11.2003 – 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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DEVELOPMENT OF EFFICIENT LUMINESCENT CONCENTRATORS BASED ON INORGANIC/ORGANIC NANOMATERIALS FOR APPLICATIONS IN SOLAR ENERGY CONVERSION

Annual Report 2008

Author and Co-Authors	Dr. Dominik Brühwiler
Institution / Company	Institute of Inorganic Chemistry, University of Zurich
Address	Winterthurerstrasse 190, CH-8057 Zürich
Telephone, E-mail, Homepage	+41 (0) 44 635 46 30, bruehwi@aci.uzh.ch, http://www.aci.uzh.ch
Project- / Contract Number	KTI 9231.2
Duration of the Project (from – to)	01.05.2008 – 30.04.2010
Date	10.12.2008

ABSTRACT

We are developing a luminescent solar concentrator (LSC) based on thin dye-zeolite-polymer layers. Efficient energy transfer systems are obtained by including organic dye molecules in the linear channels of zeolite L crystals. By using these systems as light-absorbing and emitting LSC components, self-absorption and escape cone losses can be reduced. The strong confinement of the dye molecules in the zeolite channels is further expected to lead to enhanced stability.

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THINPV

COST EFFICIENT THIN FILM PHOTOVOLTAICS FOR FUTURE ELECTRICITYGENERATION

Annual Report 2008

Author and Co-Authors	A. Feltrin, G. Bugnon, F. Meillaud, J. Bailat, C. Ballif, B. Legradic, C. Hollenstein, R. Häusermann, B. Ruhstaller, S. Wenger, P. Liska, M. Grätzel, S. Seyrling , D. Brémaud, A. Tiwari, B. Fan, J.-E. Moser, F. Nüesch
Institution / Company	Empa, ISIC-LPI-EPFL, CRPP-EPFL, ICP-ZHAW, IMT-EPFL
Address	Überlandstr. 129, CH-8600 Dübendorf
Telephone, E-mail, Homepage	+41 (0) 44 823 47 40, frank.nueesch@empa.ch, www.empa.ch
Project- / Contract Number	Co financed by the CCEM and “swisselectric research”
Duration of the Project (from – to)	2007-2010
Date	12.12.2008

ABSTRACT

This projects targets research in four thin film PV technologies being pursued in Switzerland.

Regarding the research activities on thin film silicon deposition process and characterization (Part A) several important advances have been achieved. Three plasma diagnostic tools have been developed and installed to monitor and characterize the deposition process of microcrystalline silicon in large area plasma enhanced chemical vapor deposition (PECVD) reactors; Infrared absorption spectroscopy for *in situ* and *ex situ* silane depletion measurement, optical emission spectroscopy for *in situ* silane depletion and electron temperature fluctuation measurements and *In situ* and *ex situ* laser scattering for poly-silane and powder detection. Intrinsic layers of microcrystalline silicon have been deposited at 1 nm/s. 1.2 μm thick solar cells with efficiencies up to 7.3% have been obtained.

Regarding research on novel hybrid tandem solar cells (Part B) efforts focused mainly on the monolithical integration of dye-sensitized solar cells (DSCs) and Cu(In,Ga)Se_2 (CIGS) cells as well as materials development to optimize both the dye-sensitized absorber and the transparent conducting oxide. By replacing just the back contact of the DSC cell, an increase in the transmission by more than 20% could be achieved in the near infrared domain. New ruthenium complexes were synthesized and yielded record efficiencies of 11.3% in standard DSC cells. Monolithic tandem devices using a CIGS bottom cell and a DSC top cell were successfully demonstrated with power efficiencies > 10%. Solid state organic solar cells with efficiencies >4% were achieved using photographic dyes. Hybrid cells involving organic solar cells will be considered once the current densities can be matched to the one of the other devices.

Regarding joint educational activities (Part C) this years *ThinPV workshop*, which was held from the 16th-18th November, addresses PhD students and offers both a tutorial part by world-renowned experts and a full day for student presentations.

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PECNET

AUFBAU EINES SCHWEIZER KOMPETENZ-NETZWERKS FÜR DIE SOLARE WASSERSPALTUNG MITTELS HYBRIDER PV-PEC ZELLEN

Annual Report 2008

Author and Co-Authors	Andreas Luzzi, Michael Spirig
Institution / Company	Institut für Solartechnik SPF Hochschule für Technik HSR
Address	Oberseestr. 10, 8640 Rapperswil
Telephone, E-mail, Homepage	+41 (0) 55 222 48 21, info@solarenergy.ch, www.solarenergy.ch
Project- / Contract Number	101883 / 152316
Duration of the Project (from – to)	01.10.2006 – 30.06.2008
Date	15. Januar 2009

ABSTRACT

Switzerland is internationally renown for its pioneering research & development (R&D) regarding photoelectrchemical (PEC) water-splitting. However, given a multitude of upcoming staffing, scientific and funding challenges, PECNet aimed to develop and grow a well coordinated national and international strengthened and cross-linked PEC R&D program as well as to reach extension of ressources.

PECNet's aproach was four-fold: (i) Know-how transfer from Switzerland's retiring PEC experts, (ii) pooling of Switzerland's active R&D expertise in PEC and thin-film PV relevant to PEC water-splitting, (iii) development of a 4-7 year national PEC R&D program that is aligned with international key efforts, and (iv) submission of a winning bid to the EU-FP7 for funding of a 4+3 year PEC R&D program.

After almost 2 years of operation, PECNet can look back to a series of respectful results as it has been possible to establish a strongly networked national R&D group in PEC water-splitting. More specifically, key know-how from retiring PEC-pioneers has been secured, a national PEC R&D plan implemented, a Swiss PEC centre named „PEChouse" at EPFL established, national R&D competences relevant to PEC water-splitting coordinated and grown by PEChouse, significant additional R&D funding secured (EU-FP7 NanoPEC, Marie Curie, SNF Swiss National Science Foundation, …) and international R&D collaboration expanded (IEA-HIA Annex-26).

There are no doubts that PECNet can be concluded at the beginning of 2009 as a very successful and internationally well received as well as integrated Know-how and Technology Transfer (KTT) project.

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SMARTTILE

INNOVATIVE PHOTOVOLTAIK-INDACHLÖSUNG

Annual Report 2008

Author and Co-Authors	Tamás Szacsvay
Institution / Company	3S Swiss Solar Systems AG
Address	Schachenweg 24, 3250 Lyss
Telephone, E-mail, Homepage	+41 (0) 32 391 11 11, sz@3-s.ch , www.3-s.ch
Project- / Contract Number	102682 / 153473
Duration of the Project (from – to)	01.08.2008 – 01.12.2009
Date	15.12.2008

ABSTRACT

The basic intention of the project „SmartTile“ is to finalize the development of roof integrated photovoltaic building elements, which had started within the framework of the EU-research Project “BIPV-CIS”.

Desired specific features of this new kind of PV-roof tile are integration of additional functionality, e.g. part of the mounting system, replacing the junction box, and reducing manufacturing costs by making the product design conform to industrial mass production.

Numerous design versions have been conceived and material compatibility tests have been conducted. These preparatory works will serve as a basis for further procedure, i.e. establishment of detailed product calculations, selection of the preferred version based on the generated technical and economical findings, as well as product certification to applicable norms and standards.

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ULTRALIGHT PHOTOVOLTAIC STRUCTURES

Annual Report 2008

Author and Co-Authors	Y. Leterrier, J. Rion, L. Lalande, P. Liska, A. Vasilopoulos
Institution / Company	EPFL
Address	LTC, Station 12, 1015 Lausanne
Telephone, E-mail, Homepage	+41 (0) 21 693 48 48, yves.leterrier@epfl.ch, http://ltc.epfl.ch
Project- / Contract Number	CTI 8002.1 DCS-NM
Duration of the Project (from – to)	01.01.2006 – 31.12.2008
Date	15.12.2008

ABSTRACT

The objective of this collaboration between five EPFL labs (LTC, LPI, CCLab, ICOM, CMCS) is to develop lightweight (< 1 kg/m^2), efficient and enduring prototype photovoltaic (PV) devices based on novel multilayer composite structures. The key innovation lies in the functional integration of the solar generator within a lightweight structure. The first application of these PV devices is the Solar Impulse airplane. Two technologies were initially considered: monocrystalline Si cells for the upper airplane skins and dye-sensitized cells (DSC) for the bottom skins. The company VHF Technologies joined the project on Oct. 1st, 2007, in order to develop a profiled lamination process for thin film flexible amorphous Si cells in the field of building integrated PV. The research focuses on the key materials and reliability issues needed to adapt these lightweight PV devices for specific application criteria. Attention is paid to the development of i) process methods to minimize weight without compromising PV efficiency, ii) textured polymer encapsulation and iii) production of lab-scale demonstators based on c-Si, DSC and a-Si devices integrated in a variety of polymer composite laminates.

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CENTRALE DI TEST ISAAC-TISO

QUALITÀ E RESA ENERGETICA DI MODULI FOTOVOLTAICI

Annual Report 2008

Author and Co-Authors	D. Chianese, N. Cereghetti, A. Realini, G. Friesen, E. Burà, I. Pola, T. Friesen, Roman Rudel
Institution / Company	Scuola Universitaria Professionale della Svizzera Italiana SUPSI, DACD, Istituto di Sostenibilità Applicata all'Ambiente Costruito ISAAC-TISO
Address	Via Trevano, CH – 6952 Canobbio
Telephone, E-mail, Homepage	+41 (0) 58 666 63 56; domenico.chianese@supsi.ch; www.isaac.supsi.ch
Project- / Contract Number	36508 / 153027
Duration of the Project (from – to)	01.11.2007 - 31.12.2010
Date	December 2008

ABSTRACT

During 2008 more than 6140 flashes were performed for research programmes (test centre and other projects), I-V measurements for third-parties and maintenance measurements (accreditation maintenance). A total of 458 I-V measurement, 18 determination of the temperature coefficients, 15 I-V characterization at different irradiances (200, 400, 600 and 800 W/m²), 11 outdoor initial degradation (30-60 kWh/m²) and 72 I-V determination with multiflash method were performed for third-parties.

In October 2008 the eighth quality audit, for the ISO17025 accreditation maintenance, supervised by the Swiss Accreditation Service, was successfully passed. The accreditation of the I-V measurements at different irradiances has been postponed in order to conform the laboratory to the new version (2008) of the IEC 60904-3 standard. In particular, a new procedure for the irradiance uniformity verification with two special reference modules and electronics have been designed.

The spectrale response (SR) measurement with automate filter positioning and data acquisition will be implemented with the new Pasan IIIB sun simulator. A solution, in collaboration with two industrial partner, consisting in a composition of two CCD spectroradiometers sensitive in ranges 200-1100nm and 900-1700nm respectively, was selected for the monitoring of the flash spectrum of the sun simulator

In 2008 a new 15 months test cycle (no.11) began. Thirteen different module types were chosen, in an attempt to include the greater part of available technologies: 4 mc-Si (one with *EWT backcontact)*, 4 sc-Si, 1 HIT (new version), 1 a-Si/a-Si tandem module, 1 a-Si/µc-Si (micromorph) and 2 CIS.

In test cycle 11 the power at the purchase of crystalline silicon technologies (including HIT) was on average -2.6% lower with respect to Pn but ranging from +0.5% to -10.5%. In 8 of 27 cases power at purchase was outside production tolerance.

In order to built the test stand for outdoor measurements comparison of the ER for industry, 60pcs of the new MPPT3000 have been produced.

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PERFORMANCE - ISAAC ACTIVITIES

Annual Report 2008

Author and Co-Authors	G. Friesen, I. Pola, T. Friesen, K. Nagel, F. Morini, A. Jimenez
Institution / Company	SUPSI,DACD, ISAAC-TISO
Address	Via Trevano, 6952 Canobbio, Switzerland
Telephone, E-mail, Homepage	+41 (0) 58 666 63 57, gabi.friesen@supsi.ch, http://www.isaac.supsi.ch
Project- / Contract Number	n° 019718 EU: (SES6) – Integrated project
Duration of the Project (from – to)	01.01.2006 - 31.12.2009
Date	December 2008

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 2008**. The annual reports 2006 and 2007 can be downloaded under: http://www.isaac.supsi.ch/isaac/progetti.asp?ID=33

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PHOTOVOLTAIK SYSTEMTECHNIK 2007-2010

(PVSYSTE 07-10)

Annual Report 2008

Author and Co-Authors	H. Häberlin, L. Borgna, D. Gfeller, M. Kämpfer, M. Münger, Ph. Schärf, U. Zwahlen
Institution / Company	Berner Fachhochschule, Technik und Informatik, Burgdorf
Address	Jlcoweg 1, CH - 3400 Burgdorf
Telephone, E-mail, Homepage	+41 (0)34 426 68 11, heinrich.haeberlin@bfh.ch, www.pvtest.ch
Project- / Contract Number	102234 / 152840
Duration of the Project (from – to)	01.07.2007 - 30.06.2010 (subproject monitoring from 01.01.07)
Date	12.12.2008

ABSTRACT

Purpose and Goals of the project during 2008

- Continuation of long-term monitoring of PV plants.
- Commissioning of the large PV array simulator of 100 kW ($V_{OC} \leq 810$ V / $I_{SC} \leq 156$ A)
- Modification of our PV array simulators for fully automated tests of grid-connected PV inverters.
- Tests of the sensitivity of bypass diodes against voltages and currents induced by nearby lightning currents with standard waveform 10/350µs.

Most important results in 2008

- Continuation of the long-term monitoring projects (partly since 1992) without any interruption. Inclusion of 4 more new crystalline module technologies (Kyocera KC175, Schott poly 170, Sunpower SPR215 and Solarworld SW220 poly) in the module performance comparison plant operated in co-operation with ADEV Burgdorf.
- Participation in a working group of the German PV standard commission (DKE AK373.0.3) in order to define a standard for measuring overall (total) efficiency and dynamic MPP-tracking. Tests at several inverters to find optimum power ramp patterns for dynamic inverter tests.
- PV generator simulator of 100 kW ($V_{OC} \leq 810$ V / $I_{SC} \leq 156$ A):
  In July 2008 first I-V-curve measurement showing that with a fill factor of 80% a MPP power of 100 kW can actually be reached for a short time under slight overload conditions of the two rotating DC generators used as power supplies. Commissioning was still in progress at the beginning of December 2008. By then a short test with an inverter operating at P_{DC} = 92 kW could be made. For longer operation at the full rated power of 100 kW, a somewhat stronger AC induction motor driving the smaller of the two DC generators is necessary (already ordered).
- Development of a DC line impedance stabilization network for 1000 V and 150 A in order to be able to measure conducted RF voltages also at the DC side of large inverters.
- Extension of the test software controlling the semi-automated inverter tests for automatic change of the test voltage. With this software fully automated inverter tests with our PV generator simulator of 20 kW are possible. After complete commissioning of the new 100 kW PV array simulator and a safety monitoring device hopefully also automated tests with this simulator will be possible.
- Confidential (paid) tests of different inverters for two major PV companies.
- 2 own conference contributions and co-authoring at another contribution at the 23rd EU PV conference in Valencia, 2 contributions at the 23rd PV symposium at Staffelstein/D and 2 further publications in professional journals in Switzerland and Germany.

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SOS-PVI - SECURITY OF SUPPLY PHOTO-VOLTAIC INVERTER

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

Annual Report 2008

Author and Co-Authors	Patrick Gaillard
Institution / Company	Maxwell Technologies SA
Address	Route Montena 65, CH - 1728 Rossens
Telephone, E-mail, Homepage	+41 (0) 26 411 85 39, pgaillard@maxwell.com, www.maxwell.com
Project- / Contract Number	SES6-CT-2005-019883- SOS-PVi
Duration of the Project (from – to)	01.10.2005 - 31.12.2008
Date	December 2008

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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SCHWEIZER BEITRAG ZUM IEA PVPS PROGRAMM, TASK 1

Annual Report 2008

Author and Co-Authors	Pius Hüsser
Institution / Company	Nova Energie GmbH
Address	Schachenallee 29, CH-5000 Aarau
Telephone, E-mail, Homepage	+41 (0) 62 834 03 00 / 23, pius.huesser@novaenergie.ch, www.iea-pvps.org
Project- / Contract Number	11427 / 153 243
Duration of the Project (from – to)	01.01.2008 – 31.12.2008
Date	14.01.2009

ABSTRACT

The Swiss contribution to the PVPS Programme includes:

- 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 Application Report
- Acquisition of Swiss contributions to PV Power, distribution of the magazine to approx. 280 addresses in Switzerland
- Targeted search for new contacts in the PV area, maintain a network of contacts.
- Contributions/organizations to/of national and international workshops
- PR-work in Switzerland. Reference to the programme's international publications

The results of these activities include:

- National Survey Report (NSR) based on the statistics provided by the Swiss Association of Solar Professionals and the Swiss Association of Utilities (grid-coupled installations)
- Distribution of the PV Power Magazine in July
- Task 1 meeting in Nice, France
- 1 Workshop in Valencia (September)
- Contribution to the PV Industry Workshop in Kuala Lumpur and Kolkatta
- Webmastering support for www.iea-pvps.org

Work still to be done:

- Workshop organization at the PV conference in Hamburg (Sept. 2009) and Korea (Nov. 2009)
- Participation at Task 1 Meetings in Malaysia (March) and Germany (September)

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SCHWEIZER BEITRAG ZUM IEA PVPS PROGRAMM, TASK 2 - 2008

Annual Report 2008

Author and Co-Authors	Thomas Nordmann, Luzi Clavadetscher
Institution / Company	TNC Consulting AG
Address	Seestrasse 141, CH 8703 Erlenbach
Telephone, E-mail, Homepage	+41 (0) 44 991 55 77, mail@tnc.ch, www.tnc.ch
Project- / Contract Number	14805 / 153587
Duration of the Project (from – to)	January 2008 - September 2008
Date	21.01.2009

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.

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 online at the public website http://www.iea-pvps-task2.org.

Subtask 5: Technical Assessments and Technology Trends of PV Systems This Task is developing know-how 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.

Subtask 7: Dissemination Acitivities, Educational Tools.

Task 13: A two day workshop on Performance and Reliability, held in Berlin in September 2007, was the start of a discussion to form a new Task for the continuaton of Task 2.

This project is supported by the Swiss Federal Office of Energy.

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

Annual Report 2008

Author and Co-Authors	S. Nowak, M. Ndoh Rossier, C. Spörndli
Institution / Company	NET Nowak Energie & Technologie AG
Address	Waldweg 8, CH-1717 St. Ursen
Telephone, E-mail, Homepage	+41 (0) 26 494 00 30, info@repic.ch, http://www.repic.ch
Project- / Contract Number	SECO UR-00123.01.01
Duration of the Project (from – to)	January 2008 – December 2010 (Phase II)
Date	January 2009

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. In 2008, phase II of the REPIC Platform started and promotes now also energy efficiency in international cooperation. 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. Project promotion and project realisation
3. Contribution to international networks
4. 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 2008

Author and Co-Authors	Pierre Renaud, Lionel Perret
Institution / Company	Planair SA
Address	Crêt 108a, CH - 2314 La Sagne
Telephone, E-mail, Homepage	+41 (0) 32 933 88 40, pierre.renaud@planair.ch, www.planair.ch
Project- / Contract Number	101562 / 151862
Duration of the Project (from – to)	February 2006 – December 2008
Date	12.12.2008

ABSTRACT

The objective for Task 10 is to mainstream PV in the urban environment. Task 10 work is targeted at the full array of stakeholders to assure the full value of PV, beyond the energy values, can be realized by the consumer/investor and that barriers resulting from the central station energy market are resolved. In the spring of 2008 PVPS Executive Committee meeting it was decided to extend Task 10 for the purpose of completion and packaging and dissemination of results.

Switzerland is responsible of subtask 2 (Urban Planning, Design and Development) and especially active in subtask 3 (Technical Factors).

Subtask 1 (Economic and institutional factors) led to the finalization of the report "Value analysis" detailing the various types of added values brought by photovoltaics. Reports about barriers resolution and markets drivers are still under development.

For subtask 2 (Planning, design and development), Switzerland successfully submitted a Task 10 member report about PV Urban Policies. A book Photovoltaic in the Urban Environment has been accepted. An urban planning tool is under review at the end of the year.

In subtask 3 (Technical factors), activity is more expanded than originally planned. PV Systems "added values" include growing network demand to solar generation profile match in Europe. Barriers analysis is focused on integrating with traditional network "business". Switzerland is submitting 2 case studies about PV integration into Network, including a prediction tool.

In subtask 4, (Targeted Information Development and Dissemination) a new design competition was organised in Portugal. Achieving Task 10's long term strategy of mainstream urban PV will require extensive marketing of results via stakeholder targeted communication.

Swiss representation at the two Task 10 meetings (in Langkawi (Malaysia) and in Sydney (AU)) was ensured, as well as at the Milan REE meeting to present the results of the Swiss case studies to stakeholders for the electricity grid.

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IEA-PVPS TASK 12: SWISS ACTIVITIES IN 2008

AKTUALISIERUNG DER ÖKOBILANZ VON CDTE-PV

Annual Report 2008

Author and Co-Authors	Dr. Rolf Frischknecht, Matthias Stucki
Institution / Company	ESU-services Ltd.
Address	Kanzleistr. 4, 8610 Uster
Telephone, E-mail, Homepage	Tel. +41 (0) 44 940 61 91, Fax. +41 (0) 44 940 61 94 frischknecht@esu-services.ch, www.esu-services.ch
Project- / Contract Number	11427 / 153382
Duration of the Project (from – to)	2008 – 2011
Date	11.12.2008

ABSTRACT

Life cycle assessment (LCA) is an environmental management tool for analysing, comparing and improving products or technologies. The ecoinvent database provides life cycle inventory data for currently more than 4000 unit processes. Amongst other datasets, photovoltaic life cycle inventory data is provided.

The last data update of all important types of photovoltiac plants in the Swiss ecoinvent database was made in 2007. The ecoinvent data v2.01 describe the situation of the US and European PV industry and the use of PV plants in Switzerland and Europe for the reference year 2005.

Within the Swiss contribution to the *IEA PVPS task 12, subtask 2*, the ecoinvent datasets of cadmium telluride modules and the different mounting systems were updated. This update leads to a decrease of the environmental impact of electricity from cadmium telluride laminates. The environmental impact of flat roof mounting systems decreases as well, whereas the environmental impact from mounted systems increases. Integrated (in roof or façade) systems remain approximately the same. Still, integrated systems have less environmental impact per square meter than mounted systems due to lower material demand of these systems.

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IEA SHC TASK 36: SOLAR RESOURCE KNOWLEDGE MANAGEMENT

GLOBAL RADIATION AND PV PRODUCTION FORECAST

Annual Report 2008

Author and Co-Authors	Jan Remund
Institution / Company	Meteotest
Address	Fabrikstrasse 14, 3012 Bern
Telephone, E-mail, Homepage	+41 (0) 31 307 26 26, remund@meteotest.ch, www.meteotest.ch
Project- / Contract Number	101498 / 151784
Duration of the Project (from – to)	July 2005 – June 2010
Date	12.12.2008

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 third year the validation of the global radiation forecast of Meteotest's new operational WRF (Weather research and forecasting) model was started. For three sites in the USA the model was compared to measurements and to 2 other models (ECMWF, NDFD). The uncertainty of WRF (Weather research and forecasting) model was somewhat higher than ECMWF (European Centre for Medium-Range Weather Forecasts) and NDFD (National digital forecast database) and highly dependent on the region. The uncertainty lies between 18-50% for hourly values. The breakeven of persistence is reached after 2-4 hours. In autumn a detailed benchmark for Alpine region has been started. The results will be available in summer 2009.

The solar radiation forecast has been coupled with the PV yield control tool spyce. Like this the PV production for the next two days is available for sites in Europe.

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NORMIERUNG FÜR PV-SYSTEME

IEC-TC82 UND NATIONALES TK82 FÜR PV-SYSTEME

Annual Report 2008

Author and Co-Authors	Peter Toggweiler, Thomas Hostettler
Institution / Company	Enecolo AG und Swissolar, Fachverband für Sonnenenergie
Address	Lindhofstrasse 52, 8617 Mönchaltorf
Telephone, E-mail, Homepage	+41 (0) 44 994 90 00, peter.toggweiler@enecolo.ch, www.enecolo.ch und www.swissolar.ch
Project- / Contract Number	17967 / Swissolar
Duration of the Project (from – to)	2008 - …..
Date	January 2009

ABSTRACT

Technical Committees(TCs) of the International Electrotechnical Commission (IEC) prepare international standards for electrical components and systems. Its origin comes from the security issues among production, transportation and consumption of electricity. More and more quality, environmental and economic issues are getting included in the scope of the IEC standardization process. IEC-TC 82 is dealing with standards for PV components and systems. It has five active working groups. Switzerland is involved in the following three working groups:

WG 2: Modules, non-concentrating

WG 3: Systems

WG 6: Balance-of-system components

Eight new documents were published in 2008 and many documents are under development or under revision. New in action is WG 7: Concentrator modules. For this technology application, there is a strong growing market in sunny regions with high direct radiation. Thus the development of standards is urgent. In general, the collaboration between IEC and other international organizations such as IEA-PVPS and the world bank institutions shall be improved.

The Swiss national committee has a focus on preparing comments for documents under circulation. Relevant for application in Switzerland and the Swiss PV industry are the documents about installation and safety requirements for photovoltaic (PV) generators and the different standards regarding solar inverters. In future, the trilateral collaboration DACH among Austria, Germany and Switzerland shall be better established. The Swiss team sets a focus on the revision of the “Planvorlagepflicht”, lightning protection, inverters, utility interconnection and standards for BIPV systems.

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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 2008

Author and Co-Authors	[1] S. Nowak, [1] M. Gutschner, [1] S. Gnos; [2] S. Oberholzer
Institution / Company	[1] NET Nowak Energy & Technology Ltd; [2] Bundesamt für Energie
Address	[1] Waldweg 8, CH-1717 St.Ursen; [2] 3063 Ittigen (Bern)
Telephone, E-mail, Homepage	[1] +41 (0)26 494 00 30, [2] + 41 (0)31 325 89 20, [1] stefan.nowak@netenergy.ch, [1] http://www.netenergy.ch; [2] stefan.oberholzer@bfe.admin.ch, [2] http://www.bfe.admin.ch
Project- / Contract Number	CA-011814-PV ERA NET
Duration of the Project (from – to)	1 October 2004 – 30 September 2009
Date	December 2008

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.

Concluding from four years of cooperation between national programmes within PV ERA NET and the active role to be played in the different initiatives in Europe (SET-Plan, Solar Europe Initiative, Strategic Research Agenda, etc.), there is a clear need for a network of national RTD programmes in Europe beyond the actual duration of PV ERA NET project. Four key areas are identified for continued activities: i) to exchange information on PV RTD programmes and policies, ii) to enhance tools; iii) to coordinate procedures and practices; and iv) to implement transnational PV RTD projects.

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ANALYSIS OF ANNEALING AND DEGRADATION EFFECTS ON A-SI PV MODULES

Annual Report 2008

Author and Co-Authors	Ivano Pola, Domenico Chianese, Lorenzo Fanni
Institution / Company	SUPSI, DACD, ISAAC-TISO
Address	Via Trevano, CH- 6952 Canobbio
Telephone, E-mail, Homepage	+41 58 666 63 56, ivano.pola@supsi.ch, www.isaac.supsi.ch
Project- / Contract Number	102394 / 153015
Duration of the Project (from – to)	From November 2007 to December 2009
Date	15.12.2008

ABSTRACT

The interest to thoroughly investigate the characteristics of the annealing and degradation processes comes from the encouraging results obtained with a thermally isolated a-Si PV plant [1]. Findings showed that the better thermal behaviour and annealing processes of a-Si compared to c-Si technologies compensated for significant part of losses due to the nearly horizontal roof integration.
Therefore this project aims to deeply investigate on degradation – due to sunlight (Staebler-Wronski effect) – and annealing of a-Si at different temperatures and under real outdoor operating conditions.

So far an analysis on four a-Si triple junction PV modules has been carried out. Initially the modules have been exposed to outdoor conditions for degradation. Subsequently followed different indoor annealing cycles at various temperatures and heating periods. Annealing effect showed an important recovery already at 80°C, confirming the results of high performances observed for thermal isolated a-Si plants. The most relevant parameter for annealing is temperature, which characterizes the degree of performance recovery and its evolution with time. Annealing effect on power recovery resulted much faster than degradation process. As a matter of fact, annealing at 90-100°C for a period of 8-12 hours allowed an almost complete power recovery in a-Si triple junction modules after 20 days of outdoor degradation in summer time (remaining however below power level at the exit of production line).

The next step consists in studying annealing and degradation effects directly on modules installed and monitored outdoors. Then these studies will be performed on other a-Si modules most likely of single junction.

Also, this study aims to acquire important knowledge for optimization of amorphous silicon plants and particularly in the case of BiPV solutions.

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ZERO-ENERGY SCHOOL BUILDING

EKKHARTHOF KREUZLINGEN

Annual Report 2008

Author and Co-Authors	Thomas Böhni, Tobias Buser, Benno Frauchiger
Institution / Company	Böhni Energie & Umwelt GmbH
Address	Bahnhofstrasse 43, 8500 Frauenfeld
Telephone, E-mail, Homepage	+41 (0) 52 723 00 40, info@euu.ch , www.euu.ch
Project- / Contract Number	101787 / 152201
Duration of the Project (from – to)	01.08.2006 - 31.03.2009
Date	Dezember 2008

ABSTRACT

The HPZ Ekkharhof in Kreuzlingen TG is a “Plus-Energy School”, that produces with its photovoltaic modules more energy than it needs. It was built at the end of 2006 and has successfully run since then, exceeding all expectations.

The objective for the HPZ Ekkharthof Project for the year 2008 was to get as independent as possible from the grid and to use the peak electricity inside of the building. We tried to shift the biggest electricity consumer (heat pump) to the peak of photovoltaic production at noon, which should increase the solar coverage. To controle the effects, we installed four electricit y m eters, which measure photovoltaic production, surplus feed-in, purchased electricity and the power need of the heat pump.

The change from night to day operating happened at the end of September. Like that we could compare three months, each including the necessary heating of the building. The results show a clear increase of coverage. In September only 21% of energy demand of the heat pump could be covered by solar power. After the shift in October it was more than 81% and in November still 32%.

A further optimization is hardly possible, because in winter, the photovoltaic production is usually lower than the power demand of the building, that makes the feed-in going towards zero anyway. Additionally, other electricity consumers like computers, light and kitchen advice cannot be shifted to the highest solar radiation.

The conclusion is, that it is possible to increase solar coverage and independence of the grid with simple modifications.

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BACKUP INVERTER

PRACTICAL TESTING OF BACKUP INVERTER IN SWITZERLAND

Annual Report 2008

Author and Co-Authors	Christof Bucher, Sandra Stettler, Peter Toggweiler
Institution / Company	Enecolo AG
Address	Lindhofstrasse 52, CH - 8617 Mönchaltorf
Telephone, E-mail, Homepage	+41 (0) 44 994 90 00, info@enecolo.ch, www.solarstrom.ch
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Date	01.12.2008

ABSTRACT

Conventional power inverters for photovoltaic systems need to switch off during heavy grid disturbances or power outages due to safety reasons. Therefore, even if the solar panels produced enough power to autonomously supply the load, no electricity is available in the building in case of such incidents.

In this project, a backup inverter is being tested. Its additional benefit to a conventional power inverter will be investigated. The ups-functionality (uninterruptible power supply) needs to be fast and without causing major voltage disturbances to feed critical loads such as computers or time critical processes. This project will demonstrate, whether these criteria are met.

In Summer 2008 a 2.7 kWp photovoltaic system was installed on the roof of Enecolo AG. Measurement equipment was set up and long term measurements were started. With these measurements, the main functionality (supplying the grid with pv electricity) and its efficiency (96%) were confirmed.

As a next step, the full functionality of the backup inverter must be tested. Efficiency for charging and discharging the batteries with different solar irradiation and electrical loads will be measured as well as the transient voltage behaviour of the inverter during power outages. Transient measurements will be provided in cooperation with ewz.

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des transports, de l'énergie et de la communication DETEC

Office fédéral de l'énergie OFEN

TOITURE EXPERIMENTALE 2KW FLEXCELL

TUILE PV THERMOFORMÉE

Annual Report 2008

Author and Co-Authors	Pascal Goulpié, Diego Fisher
Institution / Company	VHF Technologie SA
Address	Av Edouard Verdan 2 1400 Yverdon-les-bains
Telephone, E-mail, Homepage	+41 (0) 24 423 08 90 pascal.goulpie@flexcell.com, www.flexcell.ch
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Date	26.01.2009

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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Bundesamt für Energie BFE

PHOTOVOLTAIC ENERGY STATISTICS OF SWITZERLAND 2007

Annual Report 2008

Author and Co-Authors	Thomas Hostettler
Institution / Company	Ingenieurbüro Hostettler
Address	Luisenstrasse 14, Postfach 159, 3000 Bern 6
Telephone, E-mail, Homepage	031 302 62 26 / hostettler_engineering@compuserve.com
Project- / Contract Number	40172 / 151364
Duration of the Project (from – to)	15.12.2007 – 30.5.2008
Date	10.12.2008

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 2007, about 525 new PV plants were connected to the grid in Switzerland; 275 more than last year. The Swiss PV Market's 6.5 MWp installed peak power is more than double of the 2006 results; mainly due to the newly enhanced feed-in tariffs and substantial activities in the framework of PV-specific electricity schemes.

On account of 3.5% higher irradiation in 2007, compared to that of the last 20 years, the annual yield of all Swiss PV installations reached 875 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.

A highlight is the installed PV plant's yield development over the last 15 years. The average annual yield of smaller PV installations (up to 4 kWp) increased from about 800 kWh/kWp up to 950 kWh/kWp; that of larger PV plants even, up to 1050 kWh.