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Photovoltaic Programme Edition 2005

Summary Report, Project List, Annual Project Reports 2004 (Abstracts)

elaborated by:
NET Nowak Energy & Technology Ltd.

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Title photo:

15.4 kWp flat roof PV system using the Sarnasol product
(Photo: Sarnafil)

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Photovoltaic Programme Edition 2005

Summary Report, Project List, Annual Project Reports 2004 (Abstracts)

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PHOTOVOLTAICS

Summary Report – 2005 Edition

Reporting period 2004

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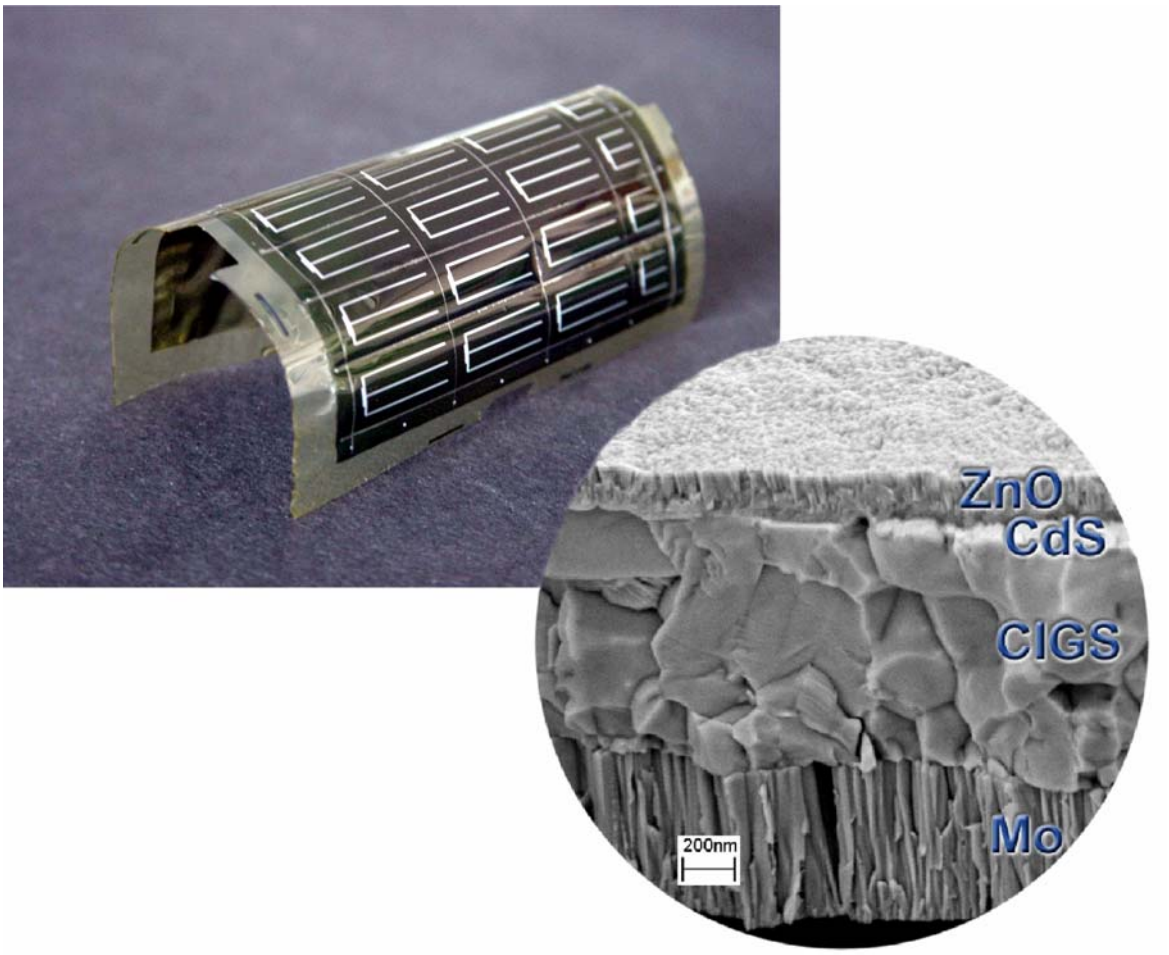

Flexible CIGS solar cells on polyimide films

The development of flexible CIGS solar cells was further pursued at the Swiss Federal Institute of Technology (ETHZ) in Zurich. A new world efficiency record of 14.1% for solar cells on flexible plastics (polyimide) substrates was achieved by optimizing the process parameters

(Photo: ETHZ)

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1. Programme priorities and targets for 2004

In 2004, the Photovoltaics (PV) Programme was influenced substantially by the economy measures decided on under the Federal Relief Programme 2003. Although the effect of these measures on research activities could up to now be kept within bounds, and was partly compensated by the programme's broad promotion base, the P+D projects segment suffered serious cutbacks. This occurred at a time when the industrial implementation and application of new systems had gained substantial momentum, thereby jeopardizing the results of long-enduring endeavors in the interests of sustainability. In view of these constraints, it was recognized as more important than ever to exert renewed efforts to identify avenues for the industrial implementation of the most promising innovations in solar cells. Despite the current standstill in the national market, the strong growth in the international photovoltaics market will help provide a foundation for further expansion of the industrial photovoltaics base in Switzerland.

In consequence, the Photovoltaics Programme continued to put emphasis on international activities. In the period covered by this report, current activities in research and development, together with projects involving pilot and demonstration plants, covered some 76 projects. This figure includes all projects benefiting from public funding. The Photovoltaics Research Programme master plan 2004-2007 [76], which has received the approval of the Federal Energy Research Commission CORE, is divided into the following sections:

Solar cells for the future

The work on **thin film solar cells** continued to focus on the principal areas: **silicon** cells (amorphous, microcrystalline), cells based on **compound semiconductors** (CIGS); and **dye cells.** Particularly for thin film silicon cells, the emphasis is on new production processes. Solar cells on flexible substrates are becoming increasingly important. Industrial implementation in the field of solar cells was vigorously pursued.

Modules and building integration

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

Electrical systems technology

Quality assurance of photovoltaic modules, power inverters and entire systems, together with **long-period observations** of these components, are themes of high relevance to practical application. Long-period measurements and the increased analysis of abnormal functioning of individual components are required to determine critical parameters and to extend service life. Based on this system-relevant work, the objective is to further increase the specific energy yield of photovoltaic installations (kWh/kWp). Contributing to this were the determined efforts during the report period to improve the prediction of the **energy yield** of solar modules. It was intended to complete the revision of the **standards** for installing grid coupled PV installations on buildings during the report period. For **island installations,** the combination of photovoltaics with other energy technologies in hybrid installations is becoming increasingly important.

Further projects and studies

This heading concerns **ecological aspects,** among other topics. Also covered are projects providing modern **tools** to aid in establishing general strategies, in planning and in plant operation. These involve the application of the latest internet technologies, computer simulations and graphics applications, including satellite communication. At the other end of the scale are the non-technical aspects central to the **developing countries.**

International institutional cooperation

International cooperation forms an important aspect in all sectors. Remaining abreast of international developments and an intensified exchange of information within the **EU** and **IEA** programmes were important objectives that were further pursued during the report period. International cooperation continued at its customary successful level. Of particular interest during the report period were the preparations for a European photovoltaics technology platform.

2. Work completed and results achieved

CELL TECHNOLOGY

In the report period, the **broad spectrum of Swiss solar cell research** was successfully pursued thanks to wide research promotion. Over the period, industrial projects supported by the CTI took on increased significance. Swiss participation in EU projects represented a further important component, although here, thin film cells suffered a temporary setback due to the funding situation within the 6th Framework Programme of the European Commission.

Thin film silicon

The University of Neuchâtel (IMT), the EPFL (CRPP), the EIAJ (Le Locle), and the NTB (Buchs), together with the companies Unaxis Solar (Trübbach, Neuchâtel) and VHF Technologies (Yverdon), are pursuing developments in the thin film silicon field, representing a mainstay of the Photovoltaics Programme. In the report period, the University of Neuchâtel completed a further important phase of the project on **thin film silicon solar cells** [1], which was characterized by substantial changes. In autumn 2004, Prof. Christophe Ballif took over the duties of Prof. Arvind Shah. In 2005, however, IMT will continue to have the benefit of Prof. Shah's extensive experience. Thus the year 2004 was characterized on the one hand by assured continuity and the maintenance of know-how at the scientific and technical levels, and on the other by the establishment of future research objectives, and not least by determined efforts to achieve industrial implementation of existing research results. This work was spearheaded by the cooperation with Unaxis and VHF Technologies. The emphasis in this SFOE project is on the key factors responsible for IMT's leading scientific position in the field of thin film silicon. Specifically, these are the efficiency of the solar cells and the deposition speed and optical absorption of the material, together with transparent oxide films (TCO) for optimum light scattering. The results of the various areas can be summarized as follows. For microcrystalline (μc-Si:H) solar cells in p-i-n film sequence, the TCO used for the front contact was optimized to reduce the short-circuit current of the cells. For microcrystalline solar cells in n-i-p sequence, an initial efficiency of 9% was obtained on glass and 7% on textured PET plastic. With micromorphous tandem cells with n-i-p sequence, an efficiency of 9.2% was achieved on glass. Further work is concentrating on ZnO as TCO material, as well as on novel spectroscopic measurement methods for characterizing solar cells.

In a new CTI project, a ***process* for the rapid deposition of microcrystalline silicon** [2] is to be developed in cooperation with Unaxis based on the KAI plasma deposition system of this company. This work will lay the foundation for the large-area (1.4 m²) industrial production of micromorphous solar cells. Microcrystalline silicon cells having an efficiency of 5.5%had already been produced in the test system, whilst those based on micromorphous silicon achieved 9.2% efficiency. In a new, and related, CTI project, CRPP at EPFL is collaborating with Unaxis to develop a new large-area ***VHF reactor* for the deposition of amorphous and microcrystalline silicon cells** [3]. Plasma excitation frequencies up to 100 MHz are to be investigated. Whilst this permits rapid deposition (≥ 4 Å/s), assuring homogeneity of the films over an area of ≥ 1 m² presents a major challenge. Initial work concerned reactor design, particularly with respect to the form of the high-frequency electrodes and the selection of process parameters. In a further new CTI project with a more analytical character, NTB in Buchs is collaborating with Unaxis to develop a **spectral response measurement system (SRMS)** [4], which is directed towards industrial production. Initial work will concern hardware design and PC control. Together with the existing SFOE project, the above CTI projects will lay the foundations for the industrial techniques required to create the production facilities for thin film silicon solar cells at Unaxis (Fig. 1).

A further independent group of projects is concerned with the development and manufacture of thin film silicon cells on plastics substrates. On the industrial side, this activity is being pursued by the IMT spin-off company VHF Technologies in Yverdon under the flexcell® trade mark. The entire production line has now been set up, and the first commercial products (e.g. a battery charger) are now on the market. The SFOE project on improving the **reliability of amorphous solar cells on polymer substrates** was successfully completed in the report period [5]. In a supplementary SFOE project concerned with the existing production technology, the process requirements for a **pilot production** of 40 kWp/a were established over the report period [6], whereby the chief bottlenecks in the process could be successfully eliminated by increasing the capacity of the individual fabrication stages (Fig. 2). The results of this work laid the foundation for a further round of investments and an expansion of production capacity. Furthermore, the objective is to further enhance the characteristics of these cells for energy production purposes.

In a new CTI project in cooperation with VHF Technologies and other partners, IMT is developing for this purpose the use of **nanostructured optical grids** to enhance the properties of flexible solar cells on plastic substrates [7]. The nanostructured plastics substrates (PET, PEN) were prepared by the company OVD Kinegram. IMT was able to produce amorphous solar cells on textured PET substrates with a stable efficiency of 7%.

In a previous CTI project with the collaboration of EIAJ in Le Locle and VHF Technologies, the use of **nanostructures** [8] had also been studied, whereby these were produced on polyimide substrates by etching. This project was completed in the report period. Notwithstanding the successful production of the required structures, the desired efficiency of the cells could not yet be achieved.

Figure 1: *Industrial KAI plasma deposition plant (Photo: Unaxis)*

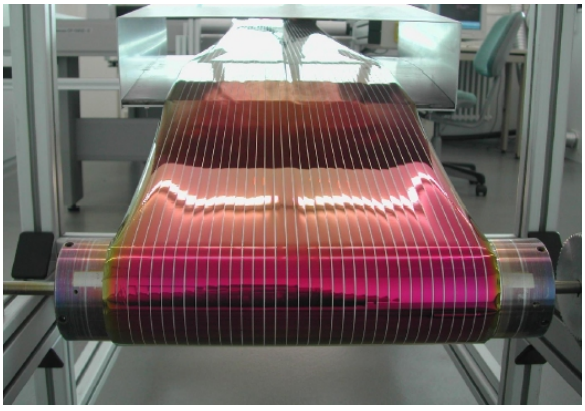

Figure 2: *Roll-to-roll production of thin film amorphous silicon solar cells (Photo: VHF)*

Crystalline silicon

HCT Shaping Systems is engaged in the EU **RE-SI-CLE** [9] project to develop new processes to extract the silicon base material from silicon waste for reuse in the production process. This is necessary to conserve the increasingly scarce raw material needed for the production of crystalline silicon solar cells. The project was completed during the report period.

The CTI **HEAT** [10] project at PSI in cooperation with HOVAL was completed during the report period. The objective was to apply silicon solar cells in a thermo-photovoltaic application for autonomously operated heating boilers. PSI is also participating in international work on the theme of thermo-photovoltaics (TPV) as part of the new EU **FULLSPECTRUM** [11] project. FULLSPECTRUM is one of the latest integrated projects in the field of photovoltaics. This combines within a single project a diversity of approaches (III-V multijunctions, TPV, intermediate band cells, molecular structures) to the more efficient exploitation of the solar radiation spectrum. In this work, efficiencies of up to 40% are the declared goal.

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. In the SFOE **FLEXCIM** [12] project, the development of flexible CIGS solar cells was further pursued in the report period. The flexible 5 x 5 cm^2 CIGS solar cells were produced on polyimide and metal films. The application of sodium as developed at the ETHZ was implemented in the project, whereby efficiencies of 10-12% were consistently achieved. Through optimized process design and control, a new world record for the efficiency of flexible solar cells on plastics (polyimide) substrates of 14.1% was achieved. This value was corroborated by independent measurements at the Fraunhofer Institute for Solar Energy Research (FhG-ISE) in Freiburg (Germany) (Fig. 3). A further increase to 15% is anticipated using reflection-free coatings. The deposition of flexible CIGS solar cells on substrates of 30 x 30 cm^2 is now at the development stage. The EU **METAFLEX** [13] project to develop a roll-to-roll process was completed during the report period. Here, the ETHZ group concentrated on CIGS deposition on polyimide, mini modules and CIGS deposition at temperatures below 450°C. Over the report period, the work was particularly directed to the use of sodium in the deposition process, for which a special post-deposition method was successfully developed and characterized. In the EU **NEBULES** [14] project, the theme of new buffer films for CIGS solar cells is under further development. Here, the ETHZ group is concentrating on the structural and electronic characterization of solar cells in relation to the different techniques used to produce the CdS buffer films. Over the report period, the interfaces of these films were analyzed in detail with respect to their structure and composition.

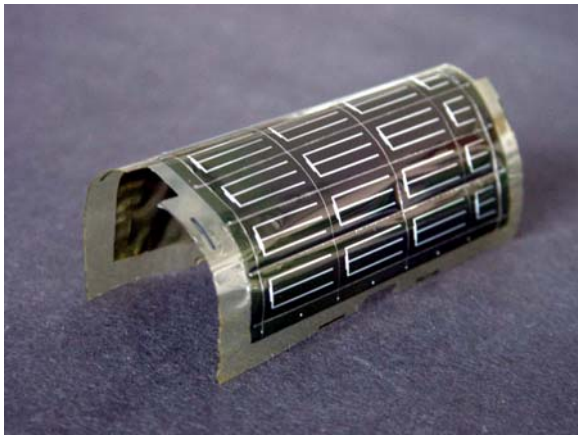

Figure 3: *Flexible CIGS sol cells on polyimide foils. (Photo: ETHZ)*

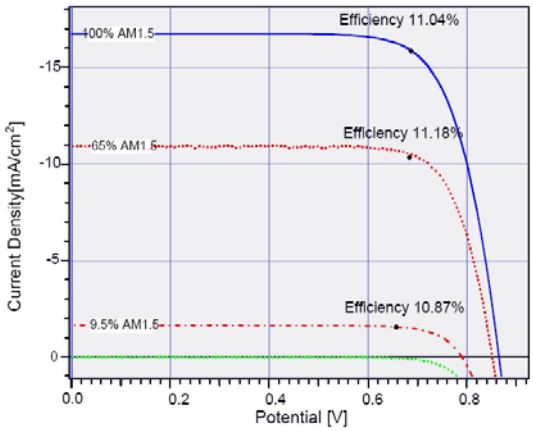

Figure 4: *I-V characteristics of dye-sensitised solar cells (Photo: EPFL)*

Dye cells

At ISIC at EPFL, the development of dye-sensitized, **nanocristalline solar cells** [15] was further pursued. During the report period, the process of dye synthesis was further developed to improve the optical properties and increase the useful temperature range. In the EU **NANOMAX** [16] project, alternative ways of producing dye cells, in particular those involving new photoelectrode designs and materials, new dyestuffs, enhanced transport properties and reduced recombination of the charge carriers, are being studied. The project was completed during the report period. On the theme of stability, which has often been a subject of interest in the past (e.g. above 1000 h, 60°C), although encouraging results could be achieved, it has not yet been possible to increase the efficiency of the cells to the desired extent (12-15%). In the project, values of 11% under an AM 1.5 reference radiation were achieved at EPFL (Fig. 4).

In a CTI project in collaboration with Greatcell Solar, the **technical scaling-up** of dye-sensitized cells [17] based on preliminary work in the *TOP NANO 21* programme is being pursued. Here, TiO_2 is produced using nanotechnology in the form of a semiconductor film on transparent conducting

substrates. The objective is to increase the no-load voltage and the operating temperature of the cell. An earlier *TOP NANO 21* project, which was concerned with **flexible dye-sensitized cells** [18], was completed in the report period. The emphasis in this was on substrates of stainless steel foil, on which dye cells were produced in the form of solid heterojunctions. In this work, efficiencies of around 3% were achieved. The new EU **MOLYCELL** [19] project is concerned with flexible organic solar cells, in which both purely organic, and hybrid nanocristalline organic, solar cells are being investigated. The latter variant is the main focus at EPFL, whereby this is to be realized using nanocristalline metal oxide films on plastics substrates. The solar cell is based on a solid heterojunction in which the absorption of light will be influenced both by molecular dyestuffs and by the choice of polymer.

In a new CTI project, LTC at EPFL is developing **photovoltaically active textiles** [20] based on dye cells in collaboration with Konarka. It is expected that this work will lead to novel photovoltaics applications.

Antenna solar cells

Fundamental work continued at the University of Bern under the solar chemistry programme on **antenna solar cells** [21], with the financial assistance of the Swiss National Science Foundation. The objective is to develop a new type of dye-sensitized solar cell based on zeolite crystals. Fundamental work is concentrating on the question of how the arrangement of the crystals at the interface to the semiconductor material affects the electronic energy transmission. Progress was achieved in the report period on improving the functionality of zeolite crystals at their ends, and in the fabrication of thin zeolite crystals.

SOLAR MODULES AND BUILDING INTEGRATION

Building integrated installations continue to represent the most important field of application of photovoltaics in Switzerland. Whilst the least expensive flat roof designs are often adopted by the solar stock exchanges, work on reducing the costs of more fully integrated systems is continuing. As, however, several successful mounting systems have now been developed (also see P+D section), the focus is increasingly shifting to the solar modules themselves. During the report period continuing emphasis was placed on developing methods for the integration of thin film cells, and on the necessary conditions for this.

In an SFOE project, Swiss Sustainable Systems (3S) studied the achievable increase in performance of crystalline solar modules using etched **reflection-free glass** [22]. To quantify the possible effects, etching was performed in an acid bath both before and after lamination. In both cases the measurements on solar modules produced with this glass showed a systematic increase in performance of approx. 2 %, i.e. a value just short of the desired 3 %. Other effects could arise at more oblique angles of incident radiation. The EU **AFRODITE** [23] project was completed during the report period. In this project, aesthetically appealing systems for PV building integration were successfully developed using back-contacted crystalline cells, and it was in fact possible to commercialize these earlier than expected [77]. As a result, the work load that had been intended for 3S could be reduced. In the new **BIPV-CIS** [24] project, the objective is to enhance the quality of photovoltaics building integration using thin film cells. Using CIS cells as a basis, roof, overhead glass and facade elements are to be developed. The main emphasis at 3S is on developing the roof elements.

Alcan Packaging continued its work on the EU **HIPROLOCO** [25] project, in which new and more economical techniques for encapsulating thin film solar cells in modules were developed. This project was completed in the report period.

Telsonic is engaged in the EU **CONSOL** [26] project to optimize the electrical contacting of CIGS solar cells. The technologies applied for this were: electrically conducting adhesive tapes, and ultrasound welding. The main variables, adhesion and contact resistance, will be measured during the climatic tests, and then optimized for both technologies. The main focus at Telsonic, which is specialized in the manufacturer of ultrasound welding equipment, will be to optimize this technology.

During the report period, the low-level standby operation of the **DEMOSITE** [27] project at EPFL was concluded by LESO. The facility displays numerous variations of systems for building integration of photovoltaics in flat roofs, gable roofs and facades. The project may be visited virtually at the www.demosite.ch website, where professional information for interested architects and other specialists may be found. The EPFL has not yet decided how this demonstration plant should be utilized in the future.

Finally, several new approaches and products for the integration of photovoltaics in buildings were tested in P+D projects (see section *pilot and demonstration projects*).

ELECTRICAL SYSTEMS TECHNOLOGY

The **main emphasis in systems technology** generally continues to lie on the quality assurance of components (modules, power inverters), systems (design, energy yield) and installations (long-period monitoring). Particularly in the current phase of rapid market growth, the experience gained from these application-related studies is vital to ensure the safety and reliability of future installations and the standardization of products. There was an acute need for action to improve the standardization and associated quality assurance of photovoltaic systems. This is also the case for components for building integration, for which no valid standards are available despite the growing market.

In the report period, the LEEE-TISO Institute of SUPSI continued its test measurements on solar models in the new **Centrale LEEE-TISO 2003-2006** [28] project. The laboratory, which is certified under ISO 17025 for measurements on class A solar simulators, was again the subject of an annual *audit,* which confirmed its precision level of ±1%. During the report period, over 2100 I-V characteristic curves (flash tests) were measured, of which 270 were performed for third parties. Measurements were made for comparison with those of other approved laboratories in Europe (ESTI-JRC and ECN), while the international round robin *test* of solar modules coordinated by NREL was continued. The corresponding results are expected in the course of 2005. Further investigations concerned the temperature coefficients of individual solar modules, measurements with varying insolation intensity and the determination of characteristic I-V curves for solar cells with capacitive properties. The measurement electronics are being redesigned for outdoor measurements on the solar modules (Fig. 5). In accordance with LEEE's current strategy, the theme of photovoltaics building integration will be treated in future as a new topic and will be accorded the necessary attention.

Figure 5: *TISO PV module test stand (Photo: LEEE TISO*

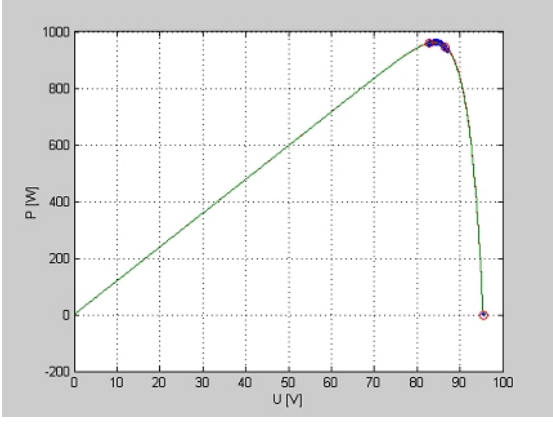

Figure 6: *Automatic determination of the power inverter maximum power points MPP (Photo: HTI Burgdorf)*

LEEE-TISO is also participating in the EU **PV Enlargement** [29] project among 10 European countries, 5 of which are in Eastern Europe, comprising 32 installations with a total capacity of 1.14 MWp. In late 2004, a total of 12 installations representing 712 kWp were in operation. LEEE-TISO is responsible here for scientific supervision, particularly concerning calibration of the measuring systems and performance measurements on the modules. From the start of the project in January 2003, 97 modules comprising various technologies (c-Si, a-Si, CIS, CdTe) and manufacturers were tested. For about half of the 53 modules based on crystalline cells, deviations from the rated output were identified. The largest negative deviation was -9.4%. However, as a counterpoint, one module developed especially for building integration showed a positive deviation of +9.6%. With thin film modules, various effects were evident, but in general the specified tolerances on rated output were upheld.

The project on **photovoltaics systems technology PVSYTE** [30] continued at the photovoltaics laboratory of Burgdorf Institute of Advanced Technology. The control and measurement software of the solar generator simulator was substantially improved in 2003 and 2004 to permit semi-automatic testing (Fig. 6). In 2004, extensive test measurements were performed on a range of new equipment (Sunways NT4000, Fronius IG 30 und IG 40, and Sunny Mini Central 6000 from SMA). The measurements included all U, I and P on the DC and AC sides, the DC-AC conversion efficiency η, the static MPP tracking resistance η_{MPPT}, the harmonic currents and cos φ for all 23 power levels. In addition, a new variable, the 'total efficiency' η_{tot}, was introduced during 2004, enabling the behaviour of network power inverters to be more fully characterized. Some of the power inverters tested displayed a significant improvement in conversion efficiency over earlier appliances, and this was often found to depend significantly on the applied DC voltage. To provide an additional computer controlled simulator for future tests, the electronic control of the small simulator (7,5 kW/12 A) was completely revised in 2004, and the voltage range increased from 75-750 V to 20-800 V. As part of this project, the long-period monitoring of the 55 power inverters treated in the previous project was continued.

During the report period, Enecolo largely completed the project on **energy rating of solar modules** [31] in cooperation with partners at home and abroad. The basis for this is the module's performance matrix (Fig. 7). The performance matrix was obtained by various experimental methods, and its properties analyzed and compared. To establish a sound performance matrix, a wide variety of high quality data is essential. However, despite the availability of knowledge on the techniques needed to establish the performance matrix, the results are not yet sufficiently consistent and precise to permit the energy rating of the modules with the intended accuracy.

Solaronix is engaged in the EU **EURO-PSB** [32] project to develop a polymer solar battery. This is a small, self-charging battery for mobile applications (Fig. 8). The principle lies in combining a novel polymer solar cell (organic solar cell) with a rechargeable lithium polymer battery. In this project, Solaronix is responsible both for the electrical circuitry between the solar cell and the battery, as well as for the entire unit. In the report period, suitable systems were devised, and a low-voltage converter with combined charge control function developed. Amorphous silicon solar cells proved to be particularly suitable for this development.

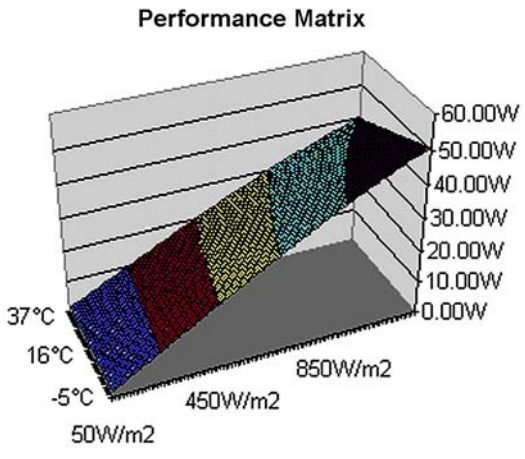

Figure 7: *Performance matrix of a solar module (Photo: Enecolo)*

Figure 8: *Application of the polymer solar battery (Photo: Varta)*

FURTHER PROJECTS AND STUDIES

The LESO laboratory at EPFL is engaged in the EU **SUNtool** [33] project, embodying a universal tool for modeling sustainability in the urban environment. Typically, this can be applied to the analysis of the energy and material flows in a group of buildings or entire urban districts (< 1 km^2). The tool is based on comprehensive analytical models of the individual systems, and combine these in a single graphical user interface. For this purpose, EPFL is developing stochastic application models, some of which have now been validated. The municipalities of Lausanne and Morges are taking part in the project as suppliers of information and data.

Enecolo is engaged in the EU **PVSAT2** [34] project. In this, satellite-based performance monitoring is being further developed, firstly by the application of more precise data from satellites, and secondly by providing a central database for PV production data. Overall, the system should then provide a reliable and economic means of monitoring small-scale photovoltaic installations, for which on-site data acquisition would be too costly. During the report period, work concentrated on improving the conversion procedure for radiation data, and developing a discrimination method to detect errors during the operation of photovoltaic installations. Enecolo is also participating in the related esa **ENVISOLAR** [35] project. The task here is to process the data currently available to esa from terrestrial observations (http://www.eomd.esa.int) in a form geared to market conditions, particularly in relation to the theme of 'solar radiation for energy applications'.

The CUEPE at the University of Geneva is engaged in the EU **Heliosat 3** [36] project to determine the energy content of solar radiation based on Meteosat data. Heliosat3 exploits among other sources the new Meteosat Second Generation (MSG) satellites to generate solar radiation data with higher temporal, spatial and spectral resolution. This data is required to improve the basis for decisions on investments, planning and management in the solar energy field. Suggested applications in photovoltaics are site optimization, and plant and network management (also see ENVISOLAR). It was shown that for locations more distant than approx. 20-25 km from the next weather station, the solar radiation calculated from satellite data is more exact . The project terminates in early 2005 with a workshop (Fig. 9).

LEEE-TISO and Solstis are partners in the new EU **PV-Catapult** [37] project. The objective of this interdisciplinary project is to identify and trigger market acceleration measures in a range of strategic sectors of photovoltaics, both in the fields of research, implementation and market activities. Among other things, a SWOT analysis of the situation in European photovoltaics is to be performed. Under the project, LEEE-TISO will deal with questions of performance measurement and prediction, while Solstis will assist in preparing a roadmap on PV-thermal hybrid collectors.

The visionary **Solarimpulse** [38] project is be led by Bertrand Piccard and carried out in collaboration with several different partners. The quest of this spectacular project is to fly around the world without landing in an aircraft driven by photovoltaic power (Fig. 10). This is a major challenge from the viewpoint of materials and design, and also concerning the generation and management of energy under extreme conditions (e.g. UV radiation, humidity, temperature, frost, ageing and mechanical vibration). Alongside the extremely economical use of energy, the aircraft's photovoltaic generator will have to supply enough energy for the momentary needs of the motor, for heating and also for energy storage to cover night flying. EPFL will assume the role of scientific consultant in the project, which will involve intensive collaboration with other organizations both in Switzerland and abroad.

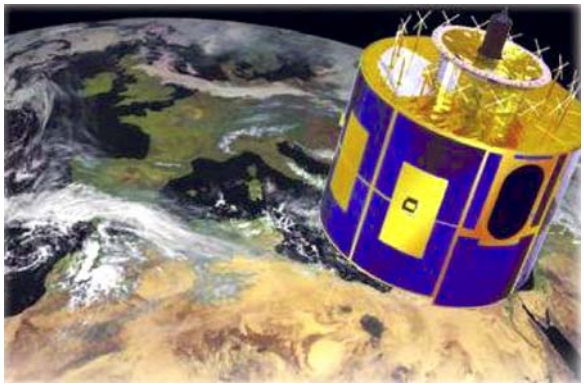

Figure 9: *Heliosat 3*
(Photo: Eumetsat)

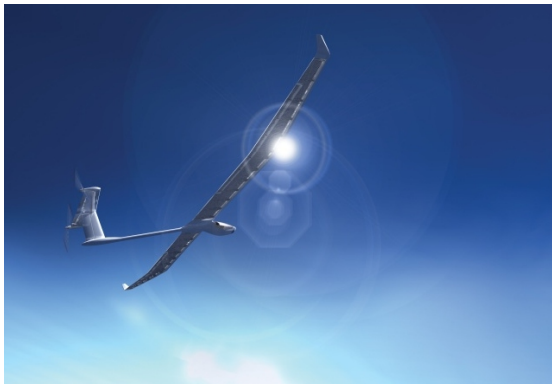

Figure 10: *aircraft driven by photovoltaics*
(Photo: Oxyde.ch – Saprisiti / ©EPFL Solar Impulse)

INTERNATIONAL COOPERATION WITHIN IEA, IEC AND PV GAP

Over the report period, participation in the IEA (IEA PVPS) photovoltaics programme was characterized by continuity both at the project level and regarding Switzerland's membership in the executive committee (ExCo) [78]. Switzerland also continued to chair this international programme during 2004. In the report period, cooperation with industry was strengthened, and the European photovoltaics industry association EPIA could be welcomed as new sponsor. Detailed information on its activities and data can be found on the http://www.iea-pvps.org website.

In IEA PVPS Task 1, which is concerned with general **information work** [39], Switzerland is represented by Nova Energie. A further national report on the photovoltaics activities in Switzerland up to 2003 [79] was prepared during the report period. This formed the basis of the 9th annual international trends report (Fig. 11) on market developments in photovoltaics in IEA countries [80]. The report was used during the report period particularly for the ongoing analyses of the photovoltaics industry on the part of the financial sector (Bank Sarasin, Credit Lyonais) [81, 82]. In the report period, a workshop with the participation of industry was organized under Swiss leadership on the occasion of the 19th European Photovoltaics Conference in Paris. The *IEA PVPS Newsletter* [83] provides information at regular intervals on the work of the IEA programme and associated themes.

TNC is responsible for the Swiss contribution to IEA PVPS Task 2 on **operating experience** [40]. In the report period, the project, which is being led by Germany, was extended for a further working period 2004-2007, and now comprises 11 participating countries (incl. the European Commission. Poland is now a permanent observer). An important new theme will cover the economic aspects of photovoltaics. The PVPS *Performance Database* [84] was enlarged to include new data, and now covers 414 photovoltaic installations in 21 countries, involving a total of around 15 000 monthly data values and 12 MWp of installed capacity. The database includes 64 Swiss installations. In 2004, two new reports on performance and insolation data were completed [85, 86].

Dynatex is participating in the work of IEA PVPS Task 3 on **island installations** [41]. The project is concerned mainly with improvements in the quality and reliability of stand-alone photovoltaic installations, and with technical questions relating to hybrid systems and batteries. The project was completed in the report period. In 2004, the last of the reports on lead-acid batteries and alternative storage systems were published [87-89].

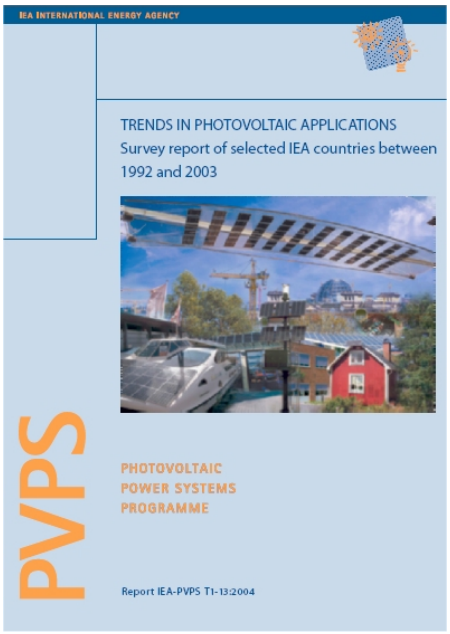

Figure 11: *IEA PVPS International Survey Report*

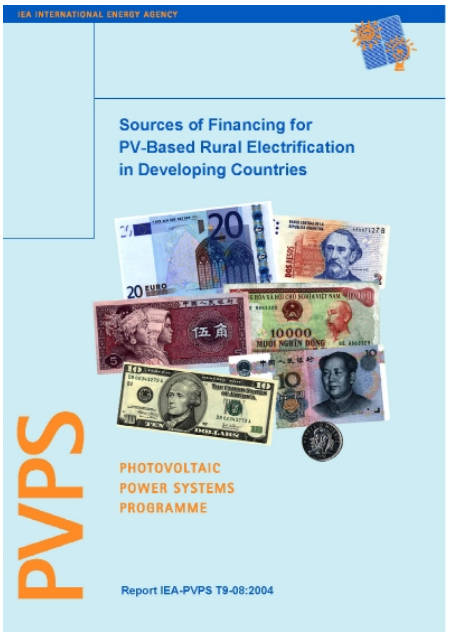

Figure 12: *IEA PVPS Task 9 report on the financing of rural electrification using photovoltaics*

Under the interdepartmental REPIC platform to promote renewable energies in international cooperation (http://www.repic.ch), which comprises seco, SDC, SAEFL and SFOE, entec is responsible for the Swiss contribution to IEA PVPS Task 9 on **photovoltaics development cooperation** [42]. In the year covered by the report, the project entered its new working phase for 2004-2008. Switzerland is responsible for coordination with bilateral and multilateral organizations. During the report period, a report on funding rural electrification schemes using photovoltaics was published in the project [90] (Fig. 12).

Alpha Real is representing Switzerland in TC 82 of IEC and is heading the working group to prepare and issue **proposals for international standards** [67] for photovoltaic systems. Alpha Real is also participating in the work of *PV-GAP* (PV Global Approval Programme), a worldwide programme on quality assurance and certification of photovoltaic systems.

EU PV-EC-NET [43] is a network project linking the national PV programme coordination centers of the 14 participating countries (http://www.pv-ec.net). The project was terminated in 2004 with the preparation of a roadmap. The supplementary EU **PV-NAS-NET** [44] project is engaged in analyzing the photovoltaics position in the new EU member countries, whereby its work will proceed along similar lines to that of PV-EC-NET (http://www.pv-nas.net). In the report period, an overall review covering the market situation and photovoltaics research activities in the above countries was published. The projects provide an excellent overview of the diverse approaches and activities in the countries concerned, and also on problems and opportunities for improvement. The new EU **PV-ERA-NET** [45] project began in 2004. In the project, the responsible ministries and programme coordination bodies in 11 countries are combined under the era-net scheme (http://www.pv-era.net). The objective here is to strengthen cooperation between the national European photovoltaics programmes, and to trigger collaborative activities in selected areas.

3. National cooperation

At the national level, the diversity of cooperative effort within the various projects was upheld over the report period. Involved in this were the federal institutes of technology, the universities of applied science, the research institutes and industry. Furthermore, cooperation with private companies was intensified, showing that interest in photovoltaics has remained unbroken despite a stagnation in the Swiss PV market.

At programme level, cooperation was maintained with numerous federal agencies, cantons and the electricity industry. In this connection, the constant interchange with OFES (or the new State Secretariat for Education and Research SER, as appropriate), CTI, SAEFL, SDC and seco, and also with the electricity industry, SESA, PSEL and the Mont Soleil Association, is worthy of special mention. The many contacts made in this way helped to provide a broader base for programme activities – an ever increasing important aspect.

4. International cooperation

International cooperation continued over the report period in its many traditional ways. The institutional cooperation taking place within IEA, IEC, PV GAP and the European network projects was mentioned above. At project level, cooperation within the EU on new and existing projects continued in 2004. This involved 20 projects under the EU's 5^{th} (or 6^{th}, as the case may be) Framework Research Programme. A further project took place in cooperation with the esa. Swiss photovoltaics proved to be relatively successful in the first round of tenders in the EU's 6th Framework Research Programme. A regular interchange takes place with those responsible for the programme in EU countries and with the teams responsible in the European Commission.

A highly significant new development was the preparatory work for the European Photovoltaics Technology Platform. Technology platforms are a new EU instrument in which research, industry and other circles are integrated in a mutually supported initiative to promote more intensive collaboration in strategically significant areas. In his function as chairman of the IEA PVPS programme, the photovoltaics programme manager took part on the work of the *Photovoltaic Technology Research Advisory Council* (PV-TRAC). During 2004, the Council – an Advisory Committee of the European Commission – prepared a report embodying a vision for the photovoltaics situation in 2030 [91], which was presented and published in September 2004. It is anticipated that the photovoltaics technology platform will become operational in 2005, enabling it to exert a positive influence on the 7th EU Framework Research Programme.

Further contacts were maintained with the international organizations concerned with development cooperation (World Bank, GEF, IFC, UNDP, GTZ, KfW, etc.). Thanks to the multiplicity of these interchanges, Swiss photovoltaics has remained very prominent on the international stage.

5. Pilot and demonstration (P+D) projects

INTRODUCTION

The Federal Relief Programme 2003 had a serious effect on the photovoltaics P+D programme. Whilst the number of active photovoltaics projects had increased slightly to over 45 projects in 2003, a total of around 35 projects were processed in the report period. At the beginning of 2005, the number of active projects did not exceed 25. Owing to the current PV P+D budgetary situation, it is not possible for the moment to support new projects in this area.

Over the report period, the P+D activities were divided between the sectors pilot installations, studies and tools, measurement campaigns and component development. In that year, the focus clearly remained on full-scale pilot testing of new components. The theme of **photovoltaics building integration** remains the focus of attention.

At present, several PV P+D projects are concerned with opportunities for introducing and applying a range of different thin film cell technologies. In several projects, the suitability of new thin film modules for photovoltaics building integration is being assessed. Previous experience confirms the positive characteristics of a number of PV elements with thin film cells for direct integration in thermally insulated roofs and facades without back ventilation of the modules.

P+D PROJECTS

New P+D Projects

In 2004 **no new P+D projects** could be started in the P+D Programme as a result of the 2003 Federal Relief Programme. This will increasingly hinder a number of Swiss firms in gaining first experience in introducing new products, and in launching new developments that could contribute to maintaining international competitiveness in photovoltaics. Whilst the world photovoltaics market has been growing at a rate of between 30% and 40% for many years now, the Swiss market has stagnated over the past 5 years. Thus a number of Swiss firms at least partially lack the necessary experience with new products and in mass markets. With some Swiss-based firms, there is a danger of these falling behind their foreign competitors. Exepted from this are those firms that were able to establish themselves early in international growth markets.

Current P+D projects

Among current projects, valuable experience was gained with the newly built roof integrated 15 kWp CPT Solar flat roof installation with amorphous thin film cells in Trevano [49] (cover photograph). The yield of 1070 kWh/kWp lay beyond initial expectations, and serves to demonstrate the optimum planning and design of this installation.

Following the two-year measurement phase in the PV ThinFilm test project [61] (Fig. 13), the excellent suitability of certain thin film modules for building integration in combination with thermal insulation could be demonstrated. The final report will contain a detailed evaluation of this work.

Also of interest are the results of the 62 kWp flat roof installation based on PowerGuard modules [52] (Fig.14). The attractiveness of this installation is underlined not only by its appealing optical features, but also by the simplicity of assembly and high yield.

Figure 13: *PV ThinFilm test modules (Photo: NET)*

Figure 14: *62 kWp installation with PowerGuard (Photo: Zagsolar)*

Current projects comprise (in chronological order):

Component development

- New PV facade system for modules with thin film cells (development of a universal facade system with or without thermal insulation for thin film cell modules. Management: Zagsolar / Wyss Aluhit) [46]

Installations

- 15.4 kWp flat roof integration CPT Solar (pilot application of a newly developed combination of amorphous thin film modules with thick plastic sheeting. Management: LEEE-TISO) [49] (cover photograph).
- 23.5 kWp PV installation in Zollhof in Kreuzlingen (flat roof demonstration installation with demo stand and large display panel at well frequented site. Management: Böhni Energie und Umwelt) [50] Fig. 15.
- Stand-alone 5.7 kWp photovoltaic installation in combination with a CHP (all year round stand-alone energy supply for 2 houses in the Jura using photovoltaics, CHP, thermal collectors and wood. Management: A. Reinhard) [75].

- 17.6 kWp flat roof installation with thin film modules at ETH Zurich (optically unobtrusive flat roof integration with amorphous cells. Management: BE Netz) [51].
- 62 kWp flat roof installation with PowerGuard solar roof panels (multifunctional PV flat roof installation with integrated thermal roof insulation, where the panels serve the dual function of thermal insulation and support structure for the modules. Management: Zagsolar) [52] Fig. 14.
- 12 kWp Solight pilot plant (pilot application of two different Solight variants, Management: Energiebüro) [53].
- Small stand-alone photovoltaic and fuel cell power supply (small PV island systems with fuel cells for backup electricity supply to the remote stand-alone measurement systems in pilot operation. Management: Muntwyler Energietechnik) [56].
- Corviglia cable car photovoltaic installation and Piz Nair installation in St. Moritz (implementation of a 17.8 kWp installation along the Corviglia cable car and a 9.7 kWp facade integrated installation in the lower and 13.5 kWp installation in the summit station on Piz Nair. Management: SunTechnics Fabrisolar) [71].
- 27 kWp AluStand installation in Hünenberg (demonstration plant using the flat roof version of the AluTec module support system (AluStand). Management: Urs Bühler Energy Systems and Engineering) [54] Fig. 16.
- 25 kWp Solgreen Kraftwerk 1 green roof installation, Zurich (exploratory use of a newly developed support module for green roofs. Management: Enecolo) [55] Fig. 17.
- 3 kWp installation at Amburnex farm (mobile island installation with auxiliary diesel generator supplying electric power to an alp, stand-alone installation. Management: Services Industriels Lausanne) [73].
- RESURGENCE – Renewable Energy Systems for Urban Regeneration in Cities of Europe (realisation of a total of 1.3 MWp PV installations in city areas in the 5 countries of Great Britain, the Netherlands, Denmark, Germany and Switzerland, EU project. Management of the Swiss part: Enecolo) [58].

Figure 15: *Zollhof PV installation in Kreuzlingen (Photo: NET)*

Figur 16: *Hünenberg 27 kWp Alustand installation (Photo: Urs Bühler Energy Systems)*

Measurement campaigns

- Wittigkofen measurement campaign (detailed measurements and evaluations with data visualization on the 80 kWp facade in Wittigkofen. Management: Ingenieurbüro Hostettler) [60] Fig. 18.
- 100 kWp Monitoraggio dell'impianto AET III PV installation (detailed measurement campaign on the renovated 100 kWp PV installation along the SFR Bellinzona-Locarno railway. Management: LEEE-TISO) [62].
- Migros PV ThinFilm test, Zurich (18 test installations with PV thin film modules in juxtaposition. Total capacity: 24.5 kWp. Management: Energiebüro) [61] Fig. 13.
- Measurement campaign on the 100 kWp installation along the A13 (Management: TNC Consulting) [63]

Figure 17: *Solgreen Kraftwerk 1 green roof installation (Photo: NET)*

Figure 18: *80 kWp facade in Wittigkofen near Bern (Photo: NET)*

Studies - tools - various projects

- Integration of the new IEC photovoltaics standard 60364-7-712 in the national installation standards NIN (amendment or replacement of the older PV installation standards. Management: Electrosuisse) [64].
- GISS building integrated solar electricity systems (study on improved implementation of building integrated solar electricity systems through reduction of administrative hindrances, information bottlenecks and higher professional competency of planners, investors and promoters. Management: SZFF Schweizerische Zentralstelle für Fenster- & Fassadenbau) [65].
- Solar *Electri* City Guide – Swiss solar electricity guide for municipalities. (Management: NET) [66].
- IEC Standards for PV systems. (Management: Alpha Real) [67].
- Swiss photovoltaic internet portal http://www.photovoltaic.ch (realisation of a comprehensive Swiss photovoltaic internet presentation with extensive information on national and international PV activities. Management: NET) [A].
- Swiss photovoltaic statistics 2004 (Management: Ing. Büro Hostettler, Energiebüro, VSE) [B].
- Solar electricity from the utilities (Management: Linder Kommunikation) [C]

Figure 19: *Detail of new NIN standard from cover photograph (Source: SEV)*

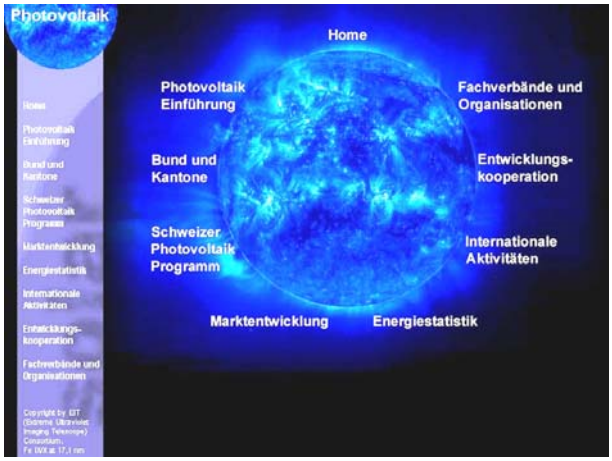

Figure 20: *Swiss Photovoltaics Internet Portal (http://www.photovoltaic.ch)*

Projects completed in 2004

The following P+D projects were completed in 2004 (in chronological order):

Component development

- Alpur photovoltaic roof installation (photovoltaics roof with thermal insulation, building integration. Management: ZAGSOLAR) [47]

Installations

- 5.5 kWp roof integration with Freestyle® integration system in Lutry (full-area photovoltaic roof installation with amorphous triple cell modules, pilot installation. Management: Solstis) [48] Fig. 21.
- 15 kWp photovoltaics roof integration at the Pfadiheim Weiermatt in Köniz (full-area photovoltaic installation using the MegaSlate® solar system on the roof of the energy optimized Pfadiheim Weiermatt. Management: 3S - Swiss Sustainable Systems) [68] Fig. 22.
- Photovoltaic obelisk (pilot realisation of attractively designed information columns with integrated stand-alone PV installations for supplying the necessary electricity. Management: Enecolo) [72] Fig. 23
- 3.9 kWp photovoltaic shading installation with CIS modules (pilot application of multifunctional translucent modules with CIS cells for combined shading of an atrium and electricity production. Management: Enecolo) [57] Fig. 24.
- 70 kWp flat roof installation at the Palexpo in Geneva (grid coupled photovoltaic roof installation at a well-frequented location combined with two charging stations for electromobiles. Management: SSES - Société Suisse pour l'Energie Solaire) [70] Fig. 25.
- 16 kWp roof integration Sunny Woods (roof integrated PV pilot installation with amorphous triple cells in a passively heated apartment building. Management: Architekturbüro Kämpfen, Naef Energietechnik) [69]

Figure 21: *Freestyle® roof integration (Photo: Solstis)*

Figure 22: *Pfadiheim Weiermatt roof integration installation in Köniz (Photo: NET)*

Figure 23: *PV Obelisk (Photo: NET)*

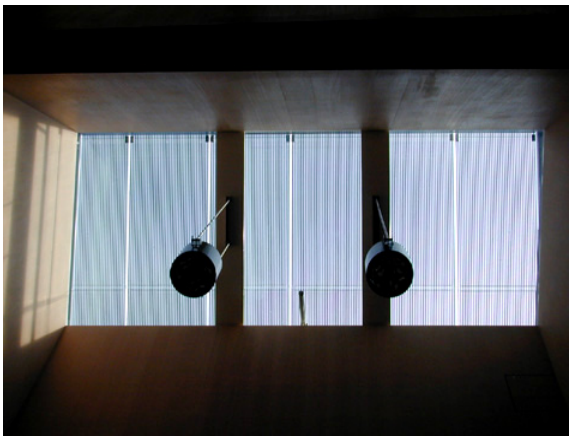

Figure 24: *PV shading installation Würth (Photo: NET)*

Figure 25: *70 kWp Palexpo flat roof installation in Geneva (Photo: NET)*

Figure 26: *Stand-alone 3 kWp roof integration in Soyhières (Photo: NET)*

Measurement campaigns

- Soyhières measurement campaign (detailed measurements and evaluations of the stand-alone 3 kWp PV roof integration in Soyhières. Management: SGI / Solstis) [59] Fig. 26.
- 47 kWp IBM installation (detailed measurement campaign on the properties of self-cleaning surface coatings of PV modules: Management: awtec, Zurich) [74]

6. Assessment of 2004 and perspectives for 2005

The international photovoltaics market is booming thanks to extensive promotion programmes and/or bonuses for photovoltaic grid supply in certain countries, with continued growth rates between 30 and 40%. In 2004, the threshold of 1000 MW was surpassed for the first time. The Swiss photovoltaics industry profited from this development, not least regarding exports. On the basis of informal enquiries, the volume of annual photovoltaics exports can be estimated at over 50 million CHF. In contrast, the Swiss photovoltaics market is stagnant: thanks to the solar and eco electricity stock exchanges it was possible to slightly increase the figures for the previous year. The IEA PVPS market data for individual countries show that Switzerland is continuing to fall behind developments, both relatively and in comparison to the largest of today's markets – particularly in Germany, Japan and the USA –, and in absolute terms is now in the middle range.

P+D projects have been the first to be affected by the cutbacks under the 2003 Federal Relief Programme, and this has had a serious effect on the content and potential of the photovoltaics programme. In 2004, no new P+D projects could be supported with SFOE funding. This development is very much to be regretted, as it will weaken an important link in the implementation chain, i.e. that between research and development on the one hand, and industrial products and processes on the other, and thus finally between research and the market. This will hit photovoltaics at a time when, following a lengthy build-up phase, stronger expansion of implementation activities was becoming apparent within the programme. P+D projects are an important link between the overall research and development effort and the task of implementing the results in industrial processes, products and installations.

Thanks to the existing broad promotion base of the photovoltaics programme, the decline in available funding for research could till now be kept within limits. EU projects benefiting from financial support from the Federal Office for Education and Science (BBW) (renamed State Secretariat for Education and Research (SER) in 2005), and – from 2004 onwards – direct support of the European Commission, and also the Commission for Technology and Innovation (CTI) (recently renamed the Innovation Promotion Agency), have also contributed to this. The efficient networking of the programme and the lively interchange between its players, both nationally and internationally, continue to provide a solid basis, and this will remain an important aspect in the future. It will be critical to tap alternative sources of finance in order to compensate the present dearth of funding for P+D projects.

In March 2004, the 5th National Photovoltaics Meeting took place at the ETH in Zurich, and was very well attended. Also, Swiss photovoltaics were well represented at the 19th European Photovoltaics Conference, which took place in Paris in June [92]. Switzerland continues to attach major importance to the exchange of information. The photovoltaics website http://www.photovoltaic.ch contains all principal reports and information, representing an essential information tool that is constantly kept up to date. From 2005 onwards, this will be particularly important, since the ENET publication service cannot be continued in its previous form, and must now be operated at a reduced level (http://www.energieforschung.ch).

On 12 April 2005, a specialist seminar on the theme of solar cell research will take place at the EMPA. The most important national event in 2005 will be the 6th National Photovoltaics Meeting in Geneva on 24/25 November 2005. Also, the 20th European Photovoltaics Conference will take place from 6 to 10 June 2005 in Barcelona (http://www.photovoltaic-conference.com), the Intersolar specialist exhibition from 23 to 25 June 2005 in Freiburg (http://www.intersolar.de) and the 20th Symposium for Photovoltaic Solar Energy from 9 to 11 March 2005 in Staffelstein.

7. List of R+D projects

(AR) Annual Report 2004 available
(FR) Final Report available
Individual annual and final reports can be downloaded from www.photovoltaic.ch
Further information can be downloaded from the internet addresses cited

[1] A. Shah, R. Tscharner, S. Faÿ, L. Feitknecht, V. Terrazzoni, E. Vallat, (arvind.shah@unine.ch), IMT, UNI-Neuchâtel, *Neuchâtel:* ***Thin film silicon modules: Contributions to low cost industrial production*** (AR, FR) / http://www.micromorph.unine.ch

[2] L. Feitknecht, A. Shah, (luc.feitknecht@unine.ch), IMT, UNI-Neuchâtel, *Neuchâtel:* ***High rate deposition of µc-Si:Hsilicon thin-film solar cell devices inindustrial KAI PE-CVD reactor*** (AR) / http://www.micromorph.unine.ch

[3] Ch. Hollenstein, A. A. Howling, B. Strahm, (christophe.hollenstein@epfl.ch), CRPP / EPFL, *Lausanne:* ***A new large area VHF reactor for high rate deposition of micro-crystalline silicon for solar cells*** (AR) / http://crppwww.epfl.ch/crpp_proc.htm

[4] F. Baumgartner, (Franz.Baumgartner@ntb.ch), NTB, *Buchs,:* ***Spectral photocurrent measurement system of thin film silicon solar cells and modules*** (AR) / http://www.ntb.ch/pv

[5] D. Fischer, (diego.fischer@flexcell.ch), VHF-TECHNOLOGIES, Le Locle: ***Étude et amélioration de la fiabilité des cellules solaires sur substrats polymers*** (FR) / http://www.flexcell.ch

[6] A. Closset, D. Fischer, Y. Ziegler, (diego.fischer@flexcell.ch), VHF-TECHNOLOGIES, Le Locle: ***Ligne pilote de fabrication de cellules solaires*** (AR, FR) / http://www.flexcell.ch

[7] V. Terrazzoni, A. Shah, (Vanessa.terrazzoni@unine.ch), IMT, UNI-Neuchâtel, *Neuchâtel:* ***Optical nano-gratings and continuous processing for improved performance flexible solar cells*** (AR) / http://www.micromorph.unine.ch

[8] H. Keppner, O. Banakh, (herbert.keppner@he-arc.ch), Haute école Arc, *Le Locle:* ***Nano-Patterning*** (AR) / http://www.eiaj.ch

[9] S. Schneeberger, (sschneeberger@hct.ch), HCT SHAPING SYSTEMS, *Cheseaux*: ***RE-Si-CLE: Recycling of Silicon Rejects from PV Production Cycle*** / http://www.hct.ch

[10] W. Durisch, (wilhelm.durisch@psi.ch), PSI, *Villigen:* ***HEAT: Heizkessel für elektrisch-autarken Betrieb mittels thermophotovoltaischem Generator*** / http://www.psi.ch

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

[12] A.N. Tiwari, M, Kaelin, D. Rudmann, D. Bremaud, T. Kämpfer, H. Zogg, (tiwari@phys.ethz.ch), ETH, *Zürich*: ***FLEXCIM: Flexible CIGS solar cells and mini-modules*** (AR) / http://www.tfp.ethz.ch

[13] A.N. Tiwari, D. Rudmann, D. Bremaud, F. Kurdesau, T. Kämpfer, H. Zogg, (tiwari@phys.ethz.ch), ETH, *Zürich*: ***METAFLEX: Towards the roll-to-roll manufacturing of cost effective CIS modules-intermediate steps*** (AR) / http://www.tfp.ethz.ch

[14] D. Abou-Ras, A. Romeo, H. Zogg, A. N. Tiwari (tiwari@phys.ethz.ch), ETH, *Zürich*: ***NEBULES: New buffer layers for efficient chalcopyrite solar cells*** (AR) / http://www.tfp.ethz.ch/

[15] M. Grätzel, A. McEvoy (michael.graetzel@epfl.ch), EPFL, *Lausanne:* ***Dye - sensitised Nanocrystalline Solar Cells*** (AR) / http://lpi.epfl.ch

[16] M. Grätzel, A. McEvoy (michael.graetzel@epfl.ch), EPFL, *Lausanne:* ***NANOMAX - dye-sensitised nanocrystalline solar cells having maximum performance*** (AR) / http://lpi.epfl.ch

[17] M. Grätzel, A. McEvoy (michael.graetzel@epfl.ch), EPFL, *Lausanne:* ***Voltage Enhancement of Dye Solar Cells at Elevated Operating Temperatures*** (AR) / http://lpi.epfl.ch

[18] M. Grätzel, R. Thampi, A. McEvoy (michael.graetzel@epfl.ch), EPFL, *Lausanne:* ***Nanocrystalline flexible photovoltaic cells based on sensitised heterojunctions*** (AR) / http://lpi.epfl.ch

[19] M. Grätzel, A. McEvoy, R. Thampi (michael.graetzel@epfl.ch), EPFL, *Lausanne:* ***MOLYCELL - Molecular Orientation, Low band-gap and new hYbrid device concepts for the improvement of flexible organic solar CELLs*** (AR) / http://lpi.epfl.ch

[20] J. A. Manson, (jan-anders.manson@epfl.ch), EPFL, *Lausanne:* **Photovoltaic Fibers and Textiles based on Nanotechnology** / http://dmxwww.epfl.ch/ltc/ltc_main.htm

[21] G. Calzaferri, (gion.calzaferri@iac.unibe.ch), UNI, *Bern:* ***Photochemische, Photoelektrochemische und Photovoltaische Umwandlung und Speicherung von Sonnenenergie*** (AR) / http://www.dcb.unibe.ch/groups/calzaferri/

[22] T. Szacsvay, C. Schilter, (cs@3-s.ch), 3S, *Bern:* ***Photovoltaics Modules with Antireflex Glass*** (AR) / http://www.3-s.ch/

[23] T. Szacsvay, P. Hofer (sz@3-s.ch), 3S, *Bern:* ***AFRODITE: Advanced facade and roof elements key to large scale building integration of photovoltaic energy*** (AR) / http://www.3-s.ch/

[24] T. Szacsvay, (sz@3-s.ch), 3S, *Bern:* ***BIPV-CIS: Improved integration of PV into existing buildings by using thin firm modules for retrofit*** (AR) / http://www.3-s.ch/

[25] W. Lohwasser, (Wolfgang.Lohwasser@alcan.com), ALCAN PACKAGING SERVICES, *Neuhausen:* ***HIPROLOCO Hight productivity and low cost for the encapsulations of thin film solar*** / http://www.alcanpackaging.com/about/eng/about_rd.php

[26] R. Züst, (reinhard.zuest@telsonic.com), TELSONIC, *Bronschhofen:* ***CONSOL - Connection Technologies for Thin-Film Solar Cells*** (AR) / http://www.telsonic.com

[27] Ch. Roecker, (christian.roecker@epfl.ch), LESO / EPFL, *Lausanne*: ***Exploitation Demosite 2003-2004*** (AR) / http://www.demosite.ch

[28] D. Chianese, A. Bernasconi, N. Cereghetti, S. Rezzonico, E. Burà, A. Realini, G. Friesen, P. Pasinelli, N. Ballarini, (domenico.chianese@supsi.ch), LEEE, SUPSI, *Canobbio:* ***Centrale LEEE-TISO Periodo VII : 2003-2004*** (AR) / http://www.leee.supsi.ch

[29] G. Friesen, A. Realini (gabi.friesen@supsi.ch), LEEE, SUPSI, *Canobbio:* ***PV Enlargement*** (AR) / http://www.leee.supsi.ch

[30] H. Häberlin, L. Borgna, Ch. Geissbühler, M. Kämpfer, U. Zwahlen, (heinrich.haeberlin@hti.bfh.ch), HTI, *Burgdorf:* ***Photovoltaik-Systemtechnik 2003-2004 (PVSYTE)*** (AR) / http://www.pvtest.ch

[31] R. Kröni, S. Stettler (robert.kroeni@enecolo.ch), ENECOLO, *Mönchaltorf:* ***Energy Rating of Solar Modules*** (AR, FR) / http://www.solarstrom.ch

[32] A. Meyer, (andreas@solaronix.com), SOLARONIX, *Aubonne:* ***The European Polymer Solar Battery EURO-PSB*** (AR) / http://www.solaronix.com

[33] N. Morel , (nicolas.morel@epfl.ch), LESO-PB/EPFL, *Lausanne*: ***SUNtool A Sustainable Urban Neighborhood Modelling Tool*** (AR) / http://lesomail.epfl.ch

[34] S. Stettler, P. Toggweiler, (info@enecolo.ch), ENECOLO, *Mönchaltorf:* ***PVSAT2 - Intelligent Performance Check of PV System Operation Based on Satellite Data*** (AR) / http://www.solarstrom.ch

[35] P. Toggweiler, (info@enecolo.ch), ENECOLO, *Mönchaltorf:* ***ENVISOLAR*** / http://www.solarstrom.ch

[36] P. Ineichen, (pierre.ineichen@cuepe.unige.ch), CUEPE, *Genève:* ***Energy specific Solar Radiation Data from Meteosat Second Generation: The Heliosat-3 project*** (AR) / http://www.unige.ch/cuepe

[37] G. Friesen, (gabi.friesen@supsi.ch), LEEE, SUPSI, *Canobbio* / P. Affolter, (pascal.affolter@solstis.ch), SOLSTIS, *Lausanne*: ***PV Catapult*** (AR) / http://www.leee.supsi.ch / http://www.solstis.ch

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

[39] P. Hüsser, (pius.huesser@novaenergie.ch), NOVA ENERGIE, *Aarau:* ***Schweizer Beitrag zum IEA PVPS Programm, Task 1*** (AR) / http://www.novaenergie.ch/

[40] Th. Nordmann, (nordmann@tnc.ch), TNC CONSULTING, *Erlenbach:* ***IEA PVPS Programm, Task 2 (Schweizer Beitrag 2004)*** (AR) / http://www.tnc.ch

[41] M. Villoz, (mvilloz@dynatex.ch), DYNATEX, *Morges:* ***IEA PVPS Task 3 Use of photovoltaic systems in stand-alone and island applications*** (AR, FR) / http://www.dynatex.ch

[42] S. Nowak, (stefan.nowak@netenergy.ch), NET, *St. Ursen:* ***Swiss Interdepartmental Platform for Renewable Energy Promotion in International Co-operation (REPIC) including Swiss contribution to IEA PVPS Task 9*** (AR) / http://www.photovoltaic.ch http://www.netenergy.ch

[43] S. Nowak, (stefan.nowak@netenergy.ch), NET, *St. Ursen:* ***PV-EC-NET: Network for Co-ordination of European and National RTD Programmes on Photovoltaic Solar Energy*** (FR) / http://www.photovoltaic.ch http://www.netenergy.ch

[44] S. Nowak, (stefan.nowak@netenergy.ch), NET, *St. Ursen:* ***PV-NAS-NET: Co-ordination of Newly Associated States and EU RTD Programmes on Photovoltaic Solar Energy*** (AR) / http://www.photovoltaic.ch http://www.netenergy.ch

[45] S. Nowak, M. Gutschner, S. Gnos (stefan.nowak@netenergy.ch), NET, *St. Ursen:* ***PV-ERA-NET: Networking and Integration of National and Regional PV Programmes*** (AR) / http://www.photovoltaic.ch http://www.netenergy.ch

8. List of P+D projects

(AR) Annual Report 2004 available
(FR) Final Report available
Individual annual and final reports can be downloaded from www.photovoltaic.ch
Further information can be downloaded from the internet addresses cited

[46] R. Durot, (r.durot@zagsolar.ch), ZAGSOLAR, *Kriens:* ***Photovoltaic- Facade Mounting System for Thin-Film-Modules*** (AR) / http://www.zagsolar.ch/

[47] R. Durot, (r.durot@zagsolar.ch), ZAGSOLAR, *Kriens:* ***Photovoltaic-Alpur-Roof - New Roofing System for Photovoltaic Modules*** (AR, FR) / http://www.zagsolar.ch/

[48] P. Affolter, (pascal.affolter@solstis.ch), SOLSTIS, *Lausanne:* ***Toiture photovoltaïque Freesty-le® de 5.5 kWp*** (AR, FR) / http://www.solstis.ch/

[49] D. Chianese, E. Burà, A. Bernasconi, (domenico.chianese@supsi.ch), LEEE-TISO, *Canobbio:* ***Flat roof integration CPT Solar*** (AR) / http://www.leee.supsi.ch

[50] Th. Böhni (boehni@euu.ch), BÖHNI ENERGIE UND UMWELT, *Frauenfeld:* ***23.5 kWp PV Anlage Zollhof Kreuzlingen*** (AR) / http://www.euu.ch

[51] B. Börlin, (boerlin@benetz.ch,), BE NETZ AG, *Luzern:* ***17.6 kWp Installation with Thin-Film-Elements on the Flat Roof at the CNB-Building of the ETHZ*** (AR) / www.benetz.ch

[52] R. Durot, (r.durot@zagsolar.ch), ZAGSOLAR, *Kriens:* **62 kWp PV-Installation - Flat Roof Integration with PowerGuard Tiles** (AR) / http://www.zagsolar.ch/

[53] Ch. Meier, R. Frei (info@energieburo.ch), ENERGIEBÜRO, *Zürich:* ***Preparation and Realisation of the Test- and Pilot Installation SOLIGHT*** (AR) / http://www.energieburo.ch

[54] U. Bühler (u.bue@bluewin.ch), URS BÜHLER ENERGY SYSTEMS AND ENGINEERING, *Cham:* ***27 kWp Anlage Hünenberg Montagesystem Alustand Freizeit- und Sportgebäude Ehret*** (AR) / http://www.alustand.ch

[55] J. Rasmussen, M. Maier (info@enecolo.ch), ENECOLO, *Mönchaltorf:* ***Solgreen Kraftwerk 1 Zürich*** (AR) / http://www.solarstrom.ch

[56] U. Muntwyler, (muntwyler@solarcenter.ch), MUNTWYLER ENERGIETECHNIK, *Zollikofen:* **Autonome Stromversorgung mit Photovoltaik und Brennstoffzellen** (AR)

[57] J. Rasmussen, K. Hürlimann, (info@enecolo.ch), ENECOLO, *Mönchaltorf:* ***Monitoring of the CIS BIPV Plant Würth in Choire*** (AR, FR) / http://www.solarstrom.ch

[58] R. Kröni (robert.kroeni@enecolo.ch), ENECOLO, *Mönchaltorf:* ***RESURGENCE - Renewable Energy Systems for Urban Regeneration in Cities of Europe*** (AR) / http://www.solarstrom.ch

[59] P. Affolter, (pascal.affolter@solstis.ch), SOLSTIS, *Lausanne:* ***Campagne de mesures de l'installation de 3 kWp à Soyhières (JU)*** (AR, FR) / http://www.solstis.ch/

[60] Th. Hostettler (Hostettler_Engineering@Compuserve.com), INGENIEURBÜRO HOSTETTLER, *Bern:* ***Messkampagne Wittigkofen*** (AR) /

[61] R. Frei, Ch. Meier, M. Haller (info@energieburo.ch), ENERGIEBÜRO, *Zürich:* ***PV-ThinFilmTest*** (AR) / http://www.energieburo.ch

[62] S. Rezzonico, E. Burà (sandro.rezzonico@supsi.ch), LEEE-TISO, *Canobbio:* ***Monitoraggio dell'impianto PV da 100 kWp AET III a Riazzino*** (AR) / http://www.leee.supsi.ch

[63] Th. Nordmann, (mail@tnc.ch), TNC CONSULTING, *Erlenbach:* ***100 kWp PV-Netzverbundanlage A13 Messkampagne, Periode 2004*** (AR) / http://www.tnc.ch

[64] J. Keller, (jost.keller@electrosuisse.ch), ELECTROSUISSE, *Fehraltorf:* ***Integration der neuen IEC Norm 60364-7-712 für Photovoltaik in die nationalen Installationsnormen NIN*** (AR, FR) / http://www.electrosuisse.ch/

[65] R. Locher, (rlocher@szff.ch), SCHWEIZERISCHE ZENTRALSTELLE FÜR FENSTER - + FASSADENBAU (SZFF), *Dietikon:* ***Gebäude-Integrierte-Solarstrom-Systeme GISS*** (AR) / http://www.szff.ch/

[66] S. Nowak, (stefan.nowak@netenergy.ch), NET, *St. Ursen:* ***Solar Electri City Guide -Schweizer Solarstromführer für die Gemeinden*** (AR) / http://www.netenergy.ch

[67] M. Real, (alphareal@access.ch), ALPHA REAL, *Zürich:* ***IEC Normenarbeit für PV Systeme*** (AR) / http://www.iec.ch

[68] T. Szacsvay, (sz@3-s.ch), 3S, *Bern:* ***Roof Integrated PV-System Scout House Weiermatt, Köniz*** (FR) / http://www.3-s.ch/

[69] R. Naef, (naef@igjzh.com), NAEF ENERGIETECHNIK, *Zürich* / B. Kämpfen, (info@kaempfen.com), BÜRO FÜR ARCHITEKTUR KÄMPFEN, *Zürich:* ***Sunny Woods - Photovoltaik-Anlage in Blechdach integriert*** / http://www.kaempfen.com/

[70] L. Keller, (office@sses.ch), SOCIETE SUISSE POUR L'ENERGIE SOLAIRE SSES, *Bern:* ***Installation photovoltaïque à Palexpo*** (FR) / http://www.sses.ch/

[71] S. Leu (info@SunTechnics.ch), SUNTECHNICS FABRISOLAR, *Küsnacht:* ***PV St. Moritz - Corvigliabahn - Piz Nair*** /(http://www.suntechnics.ch/de/unternehmen_1ak.htm)

[72] D. Ruoss, (info@enecolo.ch), ENECOLO, *Mönchaltorf* / W. Zemp, (info@zemp.tpz.ch), ZEMP+PARTNER DESIGN, *Zürich:* ***PV Obelisk - Information system in the public sector*** *(FR)* / http://www.solarstrom.ch

[73] P. Favre, (pierre-pascal.favre@lausanne.ch), SERVICES INDUSTRIELS, *Lausanne:* ***Amburnex Solar Farm (3 kWp)*** / http://www.lausanne.ch/energie

[74] A. Schlegel, (andreas.schlegel@awtec.ch), AWTEC, *Zürich:* ***Beschichtung von PV-Modulen*** (FR) / http://www.awtec.ch

[75] A. Reinhard, ***Autonome Stromversorgung mit Photovoltaik und BHKW***

[A] S. Nowak, (stefan.nowak@netenergy.ch), NET, *St. Ursen:* ***Swiss Photovoltaic Internet Portal - www.photovoltaic.ch*** (AR) / http://www.photovoltaik.ch, http://www.netenergy.ch

[B] T. Hostettler (hostettler_engineering@compuserve.com), ING. BÜRO HOSTETTLER, *Bern* / C. Meier (info@energieburo.ch),ENERGIEBÜRO, *Zürich / W. Blum,* VSE, *Aarau* : ***Photovoltaic Energy Statistics of Switzerland 2004*** (AR)

[C] E. Linder, (zuerich@linder-kom.ch), LINDER KOMMUNIKATION, *Zürich:* ***Solarstrom vom EW*** (AR) / http://www.linder-kom.ch / http://www.strom.ch/deutsch/ch-strom/solarstrom-ew.asp

9. References

[76] ***Forschungskonzept Photovoltaik 2004 – 2007***, Bundesamt für Energie, 2005, http://www.photovoltaic.ch

[77] ***www.photovoltech.be***

[78] ***Annual Report 2004,*** IEA PVPS, 2004, http://www.iea-pvps.org/

[79] ***National Survey Report on PV Power Applications in Switzerland 2003***, P. Hüsser, (pius.huesser@novaenergie.ch), Nova Energie, May 2004

[80] ***Trends in Photovoltaic Applications in selected IEA countries between 1992 and 2003***, IEA PVPS Task 1 – 13: 2004, http://www.iea-pvps.org

[81] ***Solarenergie – ungetrübter Sonnenschein?***, M. Fawer-Wasser, (matthias.fawer@sarasin.ch), Sarasin, November 2004

[82] ***Sun screen - Investment opportunities in solar power,*** M. Rogol, (michael.rogol@clsa.com), CLSA, July 2004

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

[84] ***Performance Database***, IEA PVPS Task 2, Version 1:19, June 2004, http://www.task2.org

[85] **Country reports on PV system performance, December 2004**, IEA-PVPS T2-05:2004, http://www.task2.org

[86] **The Availability of Irradiation Data, April 2004**, IEA-PVPS T2-04:2004, http://www.task2.org

[87] ***Survey of national and international standards, guidelines & QA procedures for stand-alone PV systems, 2nd edition,*** IEA PVPS T3-07:2004, May 2004, http://www.iea-pvps.org

[88] ***Managing the Quality of Stand-Alone Photovoltaic Systems, Recommended Practices***, IEA PVPS T3-15:2003, January 2004, http://www.iea-pvps.org

[89] ***Managing the Quality of Stand-Alone Photovoltaic Systems, Case studies,*** IEA PVPS T3-15(2):2003, April 2004, http://www.iea-pvps.org

[90] ***Sources of financing for PV-based rural electrification in developing countries,*** IEA PVPS T9-08:2004, May 2004, http://www.iea-pvps.org

[91] ***A Vision for Photovoltaic Technology for 2030 an Beyond***, Photovoltaic Technology Research Advisory Council (PV-TRAC), September 2004

[92] ***Die 19th European Photovoltaic Solar Energy Conference and Exhibition Paris 07. - 11. 06. 2004 aus Schweizer Sicht,*** zu beziehen bei NET, Waldweg 8, 1717 St. Ursen, info@netenergy.ch, http://www.photovoltaic.ch

10. Further information

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11. Abbreviations (incl. internet links)

General

ETH	Eidgenössische Technische Hochschule	
HES	Haute Ecole Spécialisée	
PV EZA	Swiss Platform Photovoltaics – development cooperation	http://www.photovoltaic.ch

Funding institutions

PSEL	Fund for Projects and Studies of the Swiss Electric Utilities	http://www.psel.ch

National institutions

CORE	Swiss Federal Energy Research Commission	http://www.energie-schweiz.ch
CRPP	The Plasma Physics Research Centre of Switzerland EPFL	http://crppwww.epfl.ch
CTI	The Innovation Promotion Agency	http://www.bbt.admin.ch/kti/profil/e/index.htm
CUEPE	Le Centre universitaire d'étude des problèmes de l'énergie	http://www.unige.ch/cuepe
EIAJ	Ecole d'Ingénieurs de l'Arc jurassien	http://www.eiaj.ch
EMPA	Swiss Federal Laboratories for Materials Testing and Research	http://www.empa.ch
ENET	Net for information & technologies transfer in the field of energy	http://www.energieforschung.ch
EPFL	Swiss Federal Institute of Technology Lausanne	http://www.epfl.ch
ETHZ	Swiss Federal Institute of Technology Zurich	http://www.ethz.ch
HTI Burgdorf	Berne University of Applied Sciences / School of Engineering and Information Technology	http://www.hti.bfh.ch
IMT	Institute of microtechnology University Neuchâtel	http://www-imt.unine.ch
ISIC	Institute of Chemical Sciences and Engineering	http://isic.epfl.ch
LEEE - TISO	Laboratory of Energy, Ecology and Economy - Ticino	http://www.leee.supsi.ch
LESO	Solar Energy and Building Physics Laboratory EPFL	http://lesomail.epfl.ch/
LTC	Laboratory of Polymer and Composite Technology EPFL	http://dmxwww.epfl.ch/ltc/ltc_main.htm

NIN	Low Voltage Installation Standard	http://www.electrosuisse.ch/
NTB	Interstate University of Applied Sciences of Technology Buchs	http://www.ntb.ch
OFES	Swiss Federal Office for Education and Science – New: State Secretariat for Education and Research SER	http://www.sbf.admin.ch
OPET	Swiss Federal Office for Professional Education and Technology	http://www.bbt.admin.ch
PSI	Paul Scherer Institute	http://www.psi.ch
SAEFL	The Swiss Agency for the Environment, Forest and Landscape	http://www.umwelt-schweiz.ch/buwal/eng/
SDC	Swiss Agency for Development and coorperation	http://www.deza.admin.ch
SECO	State Secretariat for Economic Affairs	http://www.seco-admin.ch
SESA	Swiss Electricity Supply Association	http://www.strom.ch
SER	State Secretariat for Education and Research	http://www.sbf.admin.ch
SFOE	Swiss Federal Office of Energy	http://www.energie-schweiz.ch
SUPSI	The University of Applied Sciences of Southern Switzerland	http://www.supsi.ch

International organisations

EU (RTD)	European Union (RTD-Programme) Community Research & Development Information Service	http://www.cordis.lu
ECN	Energy research Centre of the Netherlands	http://www.ecn.nl
EESD	Energy, Environment and Sustainable Development	http://www.cordis.lu/eesd/
ESA	European Space Agency	http://www.esa.int
ESTI	European Solar Test Installation	http://ies.jrc.cec.eu.int/Renewable_Energies.85.0.html
GEF	Global Environmental Facility	http://www.gefweb.org
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit	http://www.gtz.de
IEA	International Energy Agency	http://www.iea.org
IEA PVPS	Photovoltaic Power Systems Implementing Agreement (IEA)	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
NREL	National Renewable Energy Laboratory	http://www.nrel.gov/
PV GAP	PV Global Approval Programme	http://www.pvgap.org
UNDP	United Nations Development Programme	http://www.undp.org

Privat institutions and companies

	Unaxis	http://www.unaxis.ch

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-Board	Board of the Swiss Federal Institutes of Technology	http://www.ethrat.ch
Top Nano	Technology Oriented Programme Top Nano 21	http://www.ethrat.ch/topnano21/
SFOS	Swiss Federal Office for Statistics	http://www.statistik.admin.ch/
IGE	Swiss Federal Institute of Intellectual Property	http://www.ige.ch
	Swiss Federal Office of Metrology & Accreditation metas	http://www.metas.ch/
	Swiss Education and Research Network Switch	http://www.switch.ch
Swissolar	Swiss Task Force for Solar Energy Swissolar	http://www.swissolar.ch
SOLAR	Swiss Professionals Association for Solar Energy	http://www.solarpro.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/

Annual Report 2004

Thin film silicon modules: Contributions to low cost industrial production

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Project- / Contract Number	100 045
Duration of the Project (from – to)	01.01.2003 - 31.12.2004

ABSTRACT

IMT has done significant work on the joint optimisation of p-i-n microcrystalline silicon (µc-Si:H) solar cells and underlying rough LP-CVD ZnO layers. The effect of ZnO layer roughness on the contribution to J_{sc} from the red and near infrared light was clearly evidenced.

Work for improvement of a-Si:H p-i-n cells is under way, both for low-rate and high-rate deposition.

New records were achieved for n-i-p solar cells intended for use within flexible plastic-based modules: 9 % on glass substrates and 7 % on PET (V_{oc} = 509 mV, FF = 68 %, J_{sc} = 20.4 mA/cm^2).

The factors influencing the optical and electrical performance of ZnO layers deposited by LP-CVD were identified. Several novel schemes for improved ZnO layers were started.

Various new diagnostic tools for µc-Si:H layers and cells were introduced. Above all, Fourier-transform photoconductive spectroscopy (FTPS) was built up at IMT and shown to be a powerful tool for evaluating the quality of intrinsic a-Si:H layers.

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Annual Report 2004

High rate deposition of µc-Si:H silicon thin-film solar cell devices in industrial KAI PE-CVD reactor

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Project- / Contract Number	6928.1 IWS-IW
Duration of the Project (from – to)	1. March 2004 – 28. February 2006

ABSTRACT

The successful tandem solar cell concept as proposed by IMT Neuchâtel is industrialised in this CTI project. Note that the laboratory scale micromorph solar cells, combining an amorphous silicon (a-Si:H) absorber with a microcrystalline silicon (µc-Si:H) absorber, reach stable conversation efficiencies up to almost 12%.
This research project is based on three key issues: First, the deposition time of the µc-Si:H absorber has to be reduced, second, the device has to perform reasonably well and third, the process has to be executed in a single-chamber PECVD reactor. The development of a fabrication process for high performance thin-film (TF) silicon solar cell on industrial mass-production equipment is, thus, the aim of this project; this requires thereby a single–chamber deposition of all doped and intrinsic microcrystalline silicon layers at high deposition rates.
UNAXIS KAI PECVD reactors developed for active-matrix LCD technology have already shown to possess a high potential for cost-effective manufacturing of thin-film silicon solar cells based on amorphous silicon, as shown in a preceding CTI project between IMT, CRPP and Unaxis. This technology is presently transferred by Unaxis to KAI type PECVD systems larger than the KAI-S system at IMT.
In the present project, specific issues relating to microcrystalline devices are developed now on the small KAI–S reactor (deposition area: 0.15m^2) at IMT Neuchâtel. A successful conclusion of the project will allow for production in large size KAI reactors (area 1.4m^2) and the cost-effective production of TF micromorph modules in the future.
First cells and modules could already be fabricated in the single-chamber KAI reactors where conversion efficiencies of first microcrystalline silicon and micromorph tandem test cells of 5.5 % and 9.16 % respectively were obtained.

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Annual Report 2004

A new large area VHF reactor for high rate deposition of micro-crystalline silicon for solar cells

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Project- / Contract Number	KTI 6947.1
Duration of the Project (from – to)	1.5.2004 - 30.04.2006

ABSTRACT

A novel very high frequency (VHF) plasma source shall be applied for large area (1m^2) deposition of amorphous and microcrystalline silicon for thin film solar cell production. The use of plasma excitation frequencies (up to 100 MHz) higher than the standard 13.56 MHz excitation frequency allows to substantially increase the plasma density and gas dissociation rates without the drawback of high ion energy bombardment of the substrate and consequent damaging. Therefore higher deposition rates at good device quality can be attained. The crucial problem in very high frequency (VHF) plasma reactors, the non-uniform voltage on the RF electrode, is solved by using adequately shaped electrodes. The proof of principle of this new reactor has up till now only been made in non-reactive plasmas. In the present project, the novel RF reactor design shall be used for the first time in applications, in particular for solar cell production. The aim is to have at the end of the project a high density RF reactor operating at elevated excitation frequencies allowing industrial high rate deposition of amorphous and microcyrstalline (micromorph) silicon with a uniformity of 5-10% on large area substrates relevant for solar cells (typically 1x1 m^2).

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Annual Report 2004

Spectral photocurrent measurement system of thin film silicon solar cells and modules

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Project- / Contract Number	KTI 7112.2 EPRP-IW
Duration of the Project (from – to)	September 2004 to September 2006

ABSTRACT

The goal of our industrial project partner UNAXIS SOLAR is to become the leading equipment supplier for thin film silicon solar cells. Thereby, up scaling of an optimized laboratory thin film solar cell technology involves always losses in the efficiency of large-area modules due to losses by laser-scribing, by in homogeneities of deposited films, by low control of mass production, etc. Within this optimization process for mass fabrication the analyses of cells and modules by the spectral response measurement is one of the most powerful characterization tool. Today, there are no commercial Spectral Response Measurement System (SRMS) for thin film cells and modules available.

The goal of the present project is to develop an accurate, reliable and fast scan SRMS to analyse a-Si single and tandem cells and modules. An SR apparatus on module scale will allow obtaining the photocurrent spectra at different positions on the module. The development process will be performed in close collaboration with the industrial partner to fit the needs of an analytical tool used in an industrial R&D laboratory with the main focus to develop a mass production line.

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Annual Report 2004

Ligne pilote de fabrication de cellules solaires flexibles en silicium amorphe

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Project- / Contract Number	100540 / 150666
Duration of the Project (from – to)	01 11 2003 – 30 11 2004

ABSTRACT

The goal of the project is to implement a balanced pilot-line facility for the production of amorphous silicon solar modules on plastic film substrate.

In order to achieve an annual capacity of 40 kWpeak, the bottleneck steps of the fabrication process are addressed and suitable improvements and capacity increases are implemented.

The following results are obtained:

- Continuous coating of a-Si n-i-p solar cells by the VHF-GD process, with a production speed of 3.3 meter/hour
- Continuous top contact (ITO) structuring at > 1 meter/minute
- Series connection speed of 4.8 meter/hour
- Parallel sputtering of back contact and ITO from 2 targets
- Integration of a large area laminator with a capacity for 4 Watt products of 25 per hour.

Based on these achievements, a balanced pilot line capacity of 40 kWpeak for flexible solar cell products is realized at Yverdon-les-Bains.

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Annual Report 2004

Optical nano-gratings and continuous processing for improved performance flexible solar cells

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Project- / Contract Number	7013.1
Duration of the Project (from – to)	01 01 2004 – 01 07 2005

ABSTRACT

The Swiss company VHF-Technologies S.A. is currently developing a roll-to-roll continuous production line for thin film amorphous silicon (a-Si:H) solar cells on flexible substrates.

The goals of the reported project are to enhance the quality/price ratio of photovoltaic modules produced by VHF-Technologies as well as to open-up the promising market for flexible photovoltaic elements. Therefore, the Institute of Microtechnology (IMT) aims at transferring its technology on low-cost plastic substrates, in a way that is compatible with the specific fabrication process available at VHF-Technologies S.A.

With the goal of enhancing the performance of the photovoltaic modules, the partners propose to increase the photo-generated current by using light trapping i.e nano-structured gratings in flexible solar cells. Simultaneously, the series connections and current collection is being improved in the completed solar modules. In order to reduce the fabrication cost for modules; here, more cost-effective substrates (PET or PEN instead of polyimide), faster structuring methods and better-adapted electrodes have been investigated.

This work resulted in laboratory-scale solar cells with 7% stable efficiencies deposited on PET substrates. On the production line, VHF-Technologies has shown that PET and PEN substrates with gratings, as supplied by OVD-Kinegram A.G., are both compatible with their fabrication process. Furthermore, the series resistance and the “dead surface” of the modules have been reduced, different laser ablation processes for interconnection have been tested and a new VHF-electrode with an improved design has been installed in the reactor: 3.6% stable efficiency was achieved so far in the production line.

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Annual Report 2004

Nano-Patterning

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Project- / Contract Number	KTI 6059.1 FHS
Duration of the Project (from – to)	1.7.02 – 31.12.04

ABSTRACT

The emphasis of the project is to enhance the efficiency of thin film solar cells by means of light trapping. The industrial partner in the project VHF-Technologies who fabricate amorphous silicon cells using a p-I-n structure roll to roll process on polyimid substrates. The light trapping scenarios that are presented here have to fulfill the following requirements:

1. the process must be roll-to roll compatible.
2. the light trapping patterns must be random (in complementary with other approaches).
3. the features that lead to light trapping should be in the nano-metric range in order to turn from Lambert-scattering to Mie scattering. Therefore the project the surfaces that have to be generated are called "Super-Lambert" surfaces.
4. The cost of the technology that generates "super Lambert" surfaces must be in a reasonable relationship wit respect to the efficiency gain that can be achieved.

The latter point was estimated; the photocurrent gain from state-of the art cells (10.66 mA/cm^2) can be increased to 14 mA/cm^2 using a standard Lambert surface and even up to 17 mA/cm^2 using a super Lambert surface.

A first approach consisted to manufacture polyimide / Al /µc-Si:H substrates. Subsequent heating let Al diffuse into the grain-boundaries and creates selective sites for Al or Si etching. By that the µc-Si:H grain boundary pattern is replicated into the substrate. Some first experiments have been carried out; however the Al-oxide prevented the diffusion. A second approach consisted in SPC (solid phase crystallization) of a polyimid / a-Si:H / Al substrate. SPV could be tailored in a way that selective sites could be successfully generated. Pattern transfer for nano-scale features could be realized in the substrat.

Using such patterns, only a 5% gain in photocurrent could be achieved, far beyond the 60 % expectation. Comparing with other results we conclude, that the predicted gain can only be achieved if the surface of the cell remains unpatterned. The absorber material must smooth the pattern, if not the light will be coupled out instead of being trapped.

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Annual Report 2004

Flexible CIGS solar cells and mini-modules (FLEXCIM)

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Project- / Contract Number	100964 /151131
Duration of the Project (from – to)	01.03.2004 – 31.10.2005

ABSTRACT

Thin film Cu(In,Ga)Se_2, called CIGS, solar cells are known for high efficiency and long term stable performance. Flexible CIGS solar cells were developed on polyimide (UPILEX ^{TM}) and steel metal foils of 5 x 5 cm^2 size. No diffusion barrier layer was applied on steel or polyimide foils. A recently invented method, developed by ETHZ group, for controlled and reliable incorporation of Na in CIGS with a post-deposition treatment was applied. Flexible solar cells of 10-12% efficiency were routinely obtained on steel and polyimide foils providing the proof of concept. Further optimisation of CIGS deposition processes was focussed for solar cells on polyimide substrates. As a result cell efficiencies were further improved and measurements at ISE-Fhg Freiburg, Germany confirmed 14.1% efficiency under simulated AM1.5 standard test conditions for solar cells directly grown on Upilex polyimide films. This is the highest efficiency world record reported to date for any kind of solar cell grown on polymer films.

The measurements of quantum efficiency and reflection losses suggest that by application of antireflection coating reflection loss can be reduced and about 8-10% additional gain in cell efficiency can be expected; this would enable flexible CIGS solar cells on polymer (and on metal) foils with efficiencies exceeding 15%

Large area CIGS deposition system for 30 x 30 cm^2 substrates is in advance stage of development. Substrate heater and evaporation sources have been constructed in-house and installed in a high vacuum evaporation system also designed in-house.

Finally, CIGS solar cells in substrate configuration were developed on indium tin oxide (ITO) transparent back contacts. An intentionally grown $MoSe_2$ intermediate layer on ITO, prior to CIGS deposition, causes a significant efficiency improvement, suggesting that $MoSe_2$ can facilitate a quasi-ohmic contact on a variety of contact materials. Solar cell efficiencies of up to 11.8% are obtained using an ITO/$MoSe_2$ back contact. Such solar cells will be useful in multijunction (tandem) solar cells.

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Annual Report 2004

Towards the roll-to-roll manufacturing of cost effective CIS modules-intermediate steps (METAFLEX)

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Project- / Contract Number	BBW-NR. 01.0108 / EU PROJECT ENK6-2001-00516
Duration of the Project (from – to)	01.12.2001 – 30.11.2004

ABSTRACT

The objective of the EU project METAFLEX is to develop processes leading towards the roll-to-roll manufacturing of flexible Cu(In,Ga)Se_2 (called CIGS) solar cells and modules in future. The contributions of the ETHZ group are directed: (i) on the development of CIGS solar cells on polyimide and mini-modules in collaboration with ZSW, Stuttgart; (ii) development of a low temperature (450 °C or lower) CIGS deposition process and a method for controlled and reliable incorporation of Na in CIGS for high efficiency solar cells.

Studies were performed to investigate the influence of Na on CIGS layers and cell depending on method of Na incorporation. A novel post deposition treatment (PDT) method (patent applied) for controlled incorporation of Na in CIGS was developed. Our results suggest that In–Ga interdiffusion is hindered by Na primarily at high substrate temperatures, while at lower temperatures the interdiffusivity is low with or without Na. Cu diffusion in (Cu-poor) CIGS films is also slowed down by Na, but this effect becomes obvious only at low substrate temperatures. When the CIGS growth temperature is lowered to a critical level, such as to 370 ℃ in our experiment, the impeding influence of Na becomes apparent: A homogeneous Cu distribution cannot be established anymore in absorbers directly grown on soda lime glass (SLG), while PDT absorbers still lead to working cells. With increasing substrate temperatures, the energy barriers for Cu (and In, Ga) diffusion induced by Na can be overcome better due to the higher thermal energy, which leads to higher efficiencies for cells on SLG as the crystal quality increases. Maximum efficiencies achieved with PDT absorbers grown at temperatures of 400 ℃ an d 370 °C are 13.8 %and 1 2.4 %respe ctively are among the highest reported for such low growth temperatures.

The advantage of this novel PDT method for flexible solar cells on polymer substrates is demonstrated by developing world record efficiency (13.2% followed by 14.1%flexible sol ar cells on polymer foils. Monolithically interconnected flexible CIGS mini-modules on 5 x 5 cm^2 polymer foils were developed in collaboration with ZSW Stuttgart.

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Annual Report 2004

New buffer layers for efficient chalcopyrite solar cells (NEBULES)

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Project- / Contract Number	BBW-NR. 02.0074 / EU PROJECT ENK6-CT-2002-00664
Duration of the Project (from – to)	01.12.2002 – 31.12.2005

ABSTRACT

The contribution of the ETHZ group in this collaborative project of the European Union is focussed on the structural and electronic characterisation of Cu(In,Ga)Se_2 (CIGS) solar cells developed with different types of buffer layers.

It is known that high efficiency thin-film solar cells based on Cu(In,Ga)Se_2 (CIGS) are obtained using CdS buffer layers grown by chemical bath deposition (CBD). The highest efficiencies achieved with CdS buffer layers produced by physical vapor deposition (PVD) are significantly lower. To find reasons for this difference, structural and chemical properties of CBD- and PVD-CdS buffer layers and their interfaces with CIGS were investigated by means of bright-field, high-resolution and energy-filtered transmission electron microscopy, and also by energy-dispersive X-ray spectroscopy and scanning electron microscopy. By means of EDX, oxygen-containing surface layer could be measured at the CIGS/PVD-CdS interface, whereas such a layer could not be detected at the CIGS/CBD-CdS interface. A large defect density was detected at the PVD-CdS/CIGS interface, which is attributed to the larger lattice mismatch than at the CBD-CdS/CIGS interface. Cu diffusion from CIGS into CdS was found for the CBD- and the PVD-CdS sample. The PVD-CdS/CIGS interface turned out to be quite abrupt, whereas the CBD-CdS/CIGS interface is rather diffuse. The differences in efficiencies of solar cells with CBD- and PVD-CdS buffer layers can partly be explained by referring to the higher defect density and the probable absence of an inversion of the near-interface region from p-type to n-type at the PVD-CdS/CIGS interface.

Structural and chemical studies of interfaces between CIGS and In_2S_3 layers for application in Cd-free thin-film solar cells were investigated. The In_2S_3 layers were deposited by atomic layer deposition on CIGS layers at substrate temperatures ranging from 140°C to 240°C. Interfaces were investigated by means of scanning electron microscopy, bright-field and high-resolution transmission electron microscopy, electron diffraction, and energy-dispersive X-ray spectrometry. With increasing deposition temperature, the grain size distribution becomes sharper, whereas the grain size itself increases only slightly. An orientation relationship between CIGS-{112) and In_2S_3-{103) planes was found for the sample deposited at 210°C, whereas no orientation relationship was detected for the 240°C sample. Cu diffusion from CIGS into In_2S_3 was detected, as well as Cu depletion and In enrichment on the CIGS side of the interface. All three effects are enhanced with increasing deposition temperature. These results indicate the formation of a p-n homojunction in the CIGS layer.

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Annual Report 2004

Dye - sensitised Nanocrystalline Solar Cells

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Project- / Contract Number	EPFL ; EPFL-V
Duration of the Project (from – to)	January – December 2004

ABSTRACT

Sensitised photoelectrochemical devices are a significant technical and commercial alternative to the conventional solid-state junction photovoltaic devices for solar energy applications. The standard photovoltaic devices developed and now widely applied are solid state devices, with semiconductor layers absorbing light and thereby producing electron-hole pairs, which are subsequently separated to provide a photovoltage by junctions, either with other semiconductors or Schottky contacts with metals. In the photoelectrochemical system the contacting phase is an electrolyte. In the dye-sensitised system the recombination loss mechanism is minimised since the processes of optical absorption and charge separation take place on distinct phases within these photovoltaic cells. In consequence oppositely charged species are restricted to separate phases. Therefore device photoconversion efficiency is maintained even at low light levels.

A hybrid variant is also under investigation, the dye-sensitised solid state heterojunction, where the electrolyte phase is replaced by an organic charge transport medium. Significant progress has been made during the past year, particularly in regard to thermal stability.

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Annual Report 2004

NANOMAX - dye-sensitised nanocrystalline solar cells having maximum performance

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Project- / Contract Number	NNE5-2001-00192, BBW 01.0268-2
Duration of the Project (from – to)	36 months ; 2001 - 2004

ABSTRACT

Nano-crystalline dye sensitised solar cells (DSC) are the only validated alternative to solid state junction photovoltaic cells. As such they are not only important in their own right, but serve as a useful stimulant to innovation in photovoltaics, and to PV research and development generally. World-wide, about 60 groups are engaged in a growing effort, especially in Japan. As well as an innovative concept, these cells use materials not previously investigated for PV applications. Most work in recent years on dye-sensitised solar cells has focussed on the optimisation of cells with a standard photoelectrode design, i.e. a single sensitising dye adsorbed on nano-crystalline titanium dioxide. Although great progress has been made in terms of stability, in large part due to work on electrolyte composition and sealing, progress in efficiency has proven difficult. In the NANOMAX project, coordinated by ECN, the Netherlands Energy Research Centre and sponsored by the Commission of the European Communities, there is a break with this practice. New concepts, both for cell design and in materials, are necessary to boost the efficiency from the present 8 - 10% and compete directly on efficiency grounds with silicon solid-state devices. In NANOMAX, cells with various new photoelectrode concepts and materials are fabricated and studied. In particular, cells with thinner or multiple-layer structures are investigated. The project is now terminated, with a final report now in preparation.

BFE OFEN UFE SFOE

Annual Report 2004

Voltage Enhancement of Dye Solar Cells at Elevated Operating Temperatures

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Project- / Contract Number	7019.1
Duration of the Project (from – to):	24 months: 2004 - 2006

ABSTRACT

The present action with the industrial partner, Greatcell Solar SA (GSA) follows on the previous cooperation, also supported by KTI/CTI (project nos.5815.1 & 5480.3) "Highly Efficient Nanocrystalline Solar Cells for Indoor Applications". GSA has a specific product concept – dye-sensitised electrochemical photovoltaic cells for indoor use – in the earlier programme. The stated objectives having been attained, the present action aims at increased stability, particularly at elevated operating temperatures. It aims at the up-scaling to commercial dimensions and the technology transfer to the partner industry of the necessary nanoparticle-based technologies required for the production of such dye solar cells. It has been recognised that recombination losses are inhibited by the specific characteristics of this type of solar cell, rendering it more suitable for operation over a wider range of incident light intensiities, indoor and outdoor. Cell fabrication requires the preparation of nanoparticulate semiconductor powders, and methods of preparing mesoporous layers from these materials on transparent conducting oxide coated substrates. The layers are then sensitized to visible light by chemisorbed electroactive dyes. This photoanode is associated with a redox electrolyte and cathode to form an electrochemical photovoltaic cell. The cells will be optimised for indoor applications. This project is a key contribution to the development of the company Greatcell Solar, providing relevant information and technology for its intended product.

BFE OFEN UFE SFOE

Annual Report 2004

Nanocrystalline flexible photovoltaic cells based on sensitised heterojunctions

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Project- / Contract Number	TopNano 21 - KTI N580 2.3.
Duration of the Project (from – to)	

ABSTRACT

In the standard dye-sensitised solar cell (DSC), photoexcited electroactive dye molecules inject electrons into a semiconductor substrate, becoming positively charged. The charge-neutral state is restored by reaction with a redox electrolyte. It has been a key research topic in the Laboratory for Photonics and Interfaces. Alternatively, the positive charge can be removed by contact with a solid-state "hole conductor" or p-type semiconductor. Strategies towards flexible solid state solar cells based on nanocrystalline titanium oxide and organic solid conductors were investigated. For the flexible cell geometry a metal foil was used as substrate and a semi-transparent gold layer as counter electrode which allows light transmission (back illumination). The device performance of solid state cells based on fluorinated tin oxide coated glass on the one hand and a metal foil on the other hand were characterized and compared by measuring the current voltage curves on back and front illumination.

Annual Report 2004

MOLYCELL - Molecular Orientation, Low band-gap and new hYbrid device concepts for the improvement of flexible organic solar CELLs

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Project- / Contract Number	SES6-CT-2003-502783
Duration of the Project (from – to)	30 month, from 2004

ABSTRACT

Organic solar cells promise a strong reduction of photovoltaics (PV) cost if rapid improvements of the solar conversion efficiency and the lifetime can be achieved. There are still some crucial obstacles to overcome before a large-scale production of polymer- and or-ganic-based solar cells can be considered. The latter is the clear aim of all industrial partners here involved. The feasibility of this approach will be proven with a new generation of organic PV having better efficiency (≥ 5% on 1cm^2 glass substrates and ≥ 4% on 1cm^2 flexible substrates), longer lifetime and a production cost far below those of competing technologies based on silicon.

The programme is a multinational specific targeted research/innovation project (STREP) within the 6th. Framework Programme of the European Union.

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Annual Report 2004

Photochemische, Photoelektrochemische und Photovoltaische Umwandlung und Speicherung von Sonnenenergie

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Project- / Contract Number	76645 / 36846
Duration of the Project (from – to)	Januar 2003 – Dezember 2005

ABSTRACT

Thin silver chloride layers evolve oxygen under UV/vis illumination in aqueous solution under appropriate conditions. AgCl deposited on a conducting support photocatalyzes the oxidation of water to O_2 in the presence of a small excess of silver ions in solution. The light sensitivity in the visible part of the spectrum is due to self-sensitization caused by the formation of silver species during the photoreaction. Anodic polarization reoxidizes the reduced silver species. Experiments were carried out with gold colloids sedimented on AgCl layers. We observed that small traces of Au colloids greatly influenced the photoelectrochemical activity. The O_2 production and the photocurrent were increased by a factor of about 3, as compared to layers without gold colloids. AgCl photoanodes as well as gold colloid modified AgCl photoanodes were combined with an amorphous silicon solar cell. The AgCl layer was employed in the anodic part of a setup for photoelectrochemical water splitting consisting of two separate compartments connected through a salt bridge. A platinum electrode and an amorphous silicon solar cell were used in the cathodic part. Illumination of the AgCl photoanode and the amorphous Si solar cell led to photoelectrochemical water splitting to O_2 and H_2. For AgCl photoanodes modified with gold colloids an increased photocurrent, and consequently a higher O_2 and H_2 production were observed.

The synthesis of host-guest materials consisting of zeolite L, the channels of which are filled with dye molecules, is based on the fact that molecules can diffuse into individual channels. Functionalization of the external surface of the crystals is an option for fine-tuning their properties. Supramolecular organization of the dyes inside the channels has been shown by us to work extremely well. We can now report much progress on the functionalization of the channel entrances of zeolite L. We modified the channel entrances with reversibly and electrostatically bound, as well as covalently linked stopcock molecules. Furthermore, functionalization of the channel entrances has been achieved by a new reaction principle using protecting group chemistry. This "Sequential Functionalization of the Channel Entrances of Zeolite L Crystals" is a breakthrough in our research, because it opens the possibility to realize nearly any kind of imaginable modification of the channel ends of zeolite L or similar materials. We also reported the first successful experiments on excitation energy transfer from dyes inside the channels of zeolite L to dyes covalently bound to an external surface and from there, through a thin layer of silicon dioxide preventing electron transfer, further to a silicon semiconductor support.

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Annual Report 2004

Photovoltaics Modules with Antireflex Glass

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Project- / Contract Number	100297 / 150369
Duration of the Project	From 1th August 2003 to 1th November 2004

ABSTRACT

This project intends to quantify the increase in power-output of photovoltaic-elements thanks to the use of antireflective etched solar glass. It comprises production and performance testing of modules with and without treatment. Performance measurements are made indoor with a flasher and also outdoor. Outdoor measurements comprise power analysis subject to the angle of the incidence.

The increase in power-output of 3% or more, which the supplier express in his papers cannot be quantified. But a significant increase has been established. At least a difference of 2% can be measured in comparison with modules with and without antireflective treatment. An improvement in the behaviour with a low angle of incidence in outdoor tests can be measured. Whether it's an additional effect or just the improvement of the 2% cannot be quantified with these tests. This would be a subject of further investigations.

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Annual Report 2004

AFRODITE Advanced facade and roof elements key to large scale building integration of photovoltaic energy

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Project- / Contract Number	NNE5-2000-00178/ ENK5-CT-2000-00345
Duration of the Project (from – to)	(1. April 2001); 1. october 2001 to 1. april 2004

ABSTRACT

The objective of this work was to improve the acceptability of building integrated renewable energy conversion by developing high performance photovoltaic building elements with a high visual appeal. After an exercise of translating the visual appeal into technical specifications, a number of novelties were introduced both on the level of the crystalline silicon solar cell structure, the required production equipment and for the module manufacturing. Supporting the development of the new products with both reliability testing and an extended outdoor performance evaluation, a number of highly efficient demonstrator building elements have been manufactured.

As a main outcome of the project, the developed back contact solar cells are now manufactured and marketed by the company Photovoltech in Belgium (www.photovoltech.be).

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Annual Report 2004

BIPV-CIS (Improved integration of PV into existing buildings by using thin film modules for retrofit)

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Project- / Contract Number	503777 / BBW 03.0046
Duration of the Project (from – to)	1.1.2004 – 31.12.2007

ABSTRACT

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

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

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

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

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Annual Report 2004

CONSOL Connection Technologies for Thin-Film Solar Cells

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Project- / Contract Number	NNE5-2001-00556 / ENK6-CT-2002-00688
Duration of the Project (from – to)	01.01.2003 – 30.06.2005 (30 months)

ABSTRACT

CIGS solar modules consist of a stack of thin metallic and semi conducting layers deposited onto a glass substrate. They are connected to the external electrical circuit via two metallic tapes on the Mo back contact and the ZnAlO front contact of the stack. In this project, two connection technologies for attaching the tapes are investigated: i) using conductive adhesives and ii) ultrasonic welding. These techniques will be applied and optimised for CIGS solar cells on conventional glass substrates as well as on flexible steel foils.

These activities pursue two main goals: i) to improve the corrosion resistance, stability, and processing of the bonded contact tapes, and ii) to decrease the manufacturing costs by optimising material components and process parameters, as well as rationalising and automating process steps used for bonding. Important goals are to maintain a low contact resistivity and a low degradation in the cell efficiencies due to contact corrosion when exposed to a damp-heat environment.

All adhesive formulations investigated in this project are 1 K adhesives with epoxy-based resins with silver content. A variety of such adhesives were applied for bonding Sn-plated Cu tapes to ZnO/Mo test layers deposited on glass, steel and polyimide substrates. The contact resistivity of tapes adhered by conductive adhesive remains far below 1 Ωcm^2 during the damp-heat and thermo-cycling test.

In the case of ultrasonic welding, Al and Al-plated Ag tapes were bonded to Mo/glass and ZnO/Mo/glass test layers. These test structures were exposed to extreme environmental conditions. A good and reliable bond for the ultrasonically welded contact tapes can only be obtained with panels of the type Mo/glass, with the CIGS layer removed by scraping. For good adhesion, the welding areas must be thoroughly free of CIGS. Completely free of glass shelling was test module D with a good weldability on the Al/Ni layer additionally deposited. Further tests will be done with Al-plated Cu tapes. The 90° peel strength of ultrasonically welded tapes is significantly higher than for adhered tapes. Welded connections on Mo/glass showed an increase of the contact resistivity almost to 1 Ωcm^2 after damp-heat test. The peel strength decreased after the damp-heat test in both cases, but the decrease was more pronounced for adhered tapes.

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Annual Report 2004

Exploitation Demosite 2003-2004

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Project- / Contract Number	37468
Duration of the Project	From 1/1/2003 to 31/12/2004

ABSTRACT

In 2004, DEMOSITE continued to promote and stimulate the development of Building Integrated Photovoltaic:

- Several groups visited the site on location in Lausanne, detailed explanations were given during the tours. Most visits also include a tour of several PV pilot installations on the EPFL site. Individual visits were also conducted, mainly with foreign architects (Jpn, Fr, Ger, USA)..
- A comprehensive leaflet with details on the various systems is handed to the participants
- The Website is maintained and answers are given to questions asked either by phone or e-mail

The 8 stolen modules on the SOLFACE pavilion at DEMOSITE 1, the part of the exhibition located on the parking lot, were not replaced as the pavilion will soon be used for a demonstration of a solar thermal system (SOLABS).

Routine maintenance has been conducted, pathways in front of the last 4 pavilions cleaned and grass cut down to allow for visits. Signs have been replaced.

Possible uses for Demosite within the upcoming Task 10 are still open.

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Annual Report 2004

Centrale LEEE-TISO Periodo VII : 2003-2004

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

ABSTRACT

During 2004 more than 2100 flashes have been performed with the indoor Sun Simulator for research programmes (test centre, EU projects and other projects), I-V measurements for third-parties and maintenance measurements (accreditation maintenance, initial tests with the new thermostatic chamber, multiflash measurements). In 4 years more than 10000 flashes have been performed. In April 2004 the fourth quality audit for the ISO17025 accreditation maintenance, supervised by the Swiss Accreditation Service, was successfully passed.

For the execution of measurements at different temperatures a thermostatic chamber, specially developed for the LEEE, was acquired. In the procedure for the temperature coefficients determination measurement of the I-V characteristic at 5°C intervals, from 25°C up to 60°C, are performed.

During 2004 the measures of test cycle 9 are concluded. Stabilised power P_{15} of c-Si module is on average 4.0% lower with respect to initial power P_a. The maximum power degradation was equal to -8.1%. The mean difference between the power of c-Si modules given by the manufacturer and the measured stabilized one is -6.9%, and all the modules are within the warranty limit.

The new Maximum Power Tracker for medium term outdoor test is under development with improved features.

In the BIPV field a first SUPSI internal workshop has been organized with 11 teachers and scientific collaborators in the architectural, civil engineering and electronic areas. A documentation research about architectural aspects of different PV integration typologies has been presented.

During 2004 the LEEE website layout has been completely revised to present a systematic vision of all projects (http://www.leee.supsi.ch).

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Annual Report 2004

PV Enlargement

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Project- / Contract Number	n° OFES: 03.0004, n° EU: NNE5/2001/736
Duration of the Project (from – to)	01.01.2003 – 31.12.2006

ABSTRACT

In this project; 32 PV demonstration systems with an overall generation capacity of more than 1,140 kWp will be installed in 10 different European countries. At this stage of the project, 712 kWp, corresponding to 62% of the total project capacity, are fully operational.

One of the main objectives of the whole project is to allow a scientific energy production inter-comparison in kWh/kW_p of all installations. For the achievement of this goal a quality control on module, system and monitoring level is essential.

The LEEE-TISO is responsible for accompanying scientific measures, more precisely for calibration activities and PV module power performance tests.

23 months have elapsed since the beginning of the project and 97 modules have been measured by our laboratory. The majority of the PV cell technologies actually present on the market in Europe are tested and compared within the framework of this project (mono-crystalline Si, EFG Si, poly-crystalline Si, amorphous Si, CdTe, CIS, hybrid cells, etc.).

The performance tests enable the difference between the purchased module power and the declared power (P_n) to be quantified and measures the possible degradation or recovery occurring during the first days of exposure.

A summary of the results obtained by the LEEE-TISO in 2004 will be given in this report. All technologies will be briefly discussed.

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Annual Report 2004

Photovoltaik-Systemtechnik 2003-2004 (PVSYTE)

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Project- / Contract Number	100451
Duration of the Project (from – to)	01.01.2003 – 31.12.2004 (31.12.2006)

ABSTRACT

Purpose and Goals of the project during 2004

- Extended semi-automated tests of grid-connected PV inverters from different manufacturers at least for 3 different DC voltages using the PV array simulators 25 kW and 7.5 kW of the PV laboratory.
- Continuation of long-term monitoring of PV plants after end of former monitoring project LZPV2.
- Ongoing participation in national network of competence BRENET (building & renewable energy network).

Most important results in 2004

- Extended semi-automated tests performed at several new inverters (NT4000, IG30, IG40, SMA Mini Central 6000) with the new PV array simulators on 3 to 5 different DC voltage levels. In the same measurement run, DC-AC conversion efficiency, harmonic currents, power factor, static and dynamic maximum-power-point-tracking (MPPT-) efficiency vs. power can be determined.
- PV array simulators: Significant extension of voltage range to 20 V – 800 V instead of 75 V – 750 V and development of new hardware for the control circuits for the smaller PV array simulator of the PV laboratory of HTI in Burgdorf to be prepared better for tests of inverter with unusual specifications.
- To increase measurement accuracy of MPP-tracking efficiency η_{MPPT} further, it is now also possible to use *measured* P_{MPP}-values for each power level for determination of η_{MPPT} instead of extrapolated I-V-curves.
- Introduction of a new quantity $\eta_{tot} = \eta \cdot \eta_{MPPT}$ that can describe overall behaviour of grid-connected PV inverters much better than only DC-AC conversion efficiency η.
- In course of the investment program of the University of Applied Science Bern (BFH) for 2004, a programmable AC/DC source of 3·5kW (0-2.5kHz) and an IR-camera could be ordered and commissioned, which will extend the test possibilities of the PV laboratory considerably in the future.
- Continuation of long-term monitoring of PV plants. Realisation of automatic data transmission to HTI by means of a GSM modem for the last plant with analytical monitoring with manual readout. Planning of monitoring equipment and its overvoltage protection for large PV plant Wankdorf in Bern.
- (Mandatory) change of computer network and operating systems to XP on most PC's used in the project.
- Staff change: 3 new assistants taking over the project work and responsibility from former assistants.
- 4 conference contributions at the 19th EU PV Conf. in Paris, an oral presentation at the Swiss national PV conference in Zurich and 2 publications in scientific newspapers on different project results.

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Annual Report 2004

Energy Rating of Solar Modules

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Project- / Contract Number	47456 / 87538
Duration of the Project (from – to)	Jan. 2003 – Dec. 2003

ABSTRACT

The Performance Matrix forecasts the electric power of a solar module against solar irradiance and ambient temperature. To determine the performance matrix of a solar module, first its power is measured at different irradiances and temperatures; then a mathematical model is used to fit a plane through the power data.

In this project the suitability of different measurement methods and mathematical models to create a Performance Matrix was analysed. For this purpose 3 modules BP580 (monocrystalline) and 3 Kyocera modules (polycristalline) were measured indoor and outdoor. These measurement data were used to create Performance Matrices of the modules with different mathematical models.

It revealed that the measurement data have to cover a broad range of temperatures and irradiances to build a reliable basis for the creation of a Performance Matrix. Therefore indoor measurements where any temperature and irradiance can be adjusted are very adequate. But with indoor measurements various external factors like diffuse irradiance, wind, albedo and ambient temperature are missing. Outdoor measurements on the other hand are appropriate to build a Performance Matrix, if the measurement can be done automatically and for a sufficient time (weeks to months). Compared to measurements with a suntracker, the measurements on a fixed rack include angle of incidence variations. If the instantaneous power at maximum power point is measured instead of the whole I-V curve, at varying weather conditions MPPT errors occur. These have to be excluded from the final analysis.

The analysed mathematical models differ in complexicity, required input values, compressibility and physical background. With exception of a very simple linear model, they all showed similar results and uncertainties.

The Performance Matrices of the 6 modules were used to forecast the specific energy yield for different standard days and the yearly specific energy yield for the locations Zurich, St.Moritz and Lagos. All Kyocera modules achieved in average up to 4.2 % higher specific yields than the modules BP580. It is not sure yet, if this difference is significant enough in relation to the until now obtained uncertainty of the yearly specific energy yield prediction of approximately ± 3%. The difference between the two module types is much smaller if the energy predicition is based on indoor measurements, which could be due to different behaviour under outdoor conditions. But this has to be analysed further.

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Annual Report 2004

The European Polymer Solar Battery EURO-PSB

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Project- / Contract Number	02.0248 / ENK5-CT-2002-00687
Duration of the Project (from – to)	01.01.2003 to 31.12.2005

ABSTRACT

The aim of EURO-PSB is to develop a self-rechargeable solar battery, i.e. a « tandem module », by coupling a polymer solar cell together with a thin rechargeable lithium-polymer battery. This completely new tandem device would have performances (capacity, voltage, current output, etc) and specifications (dimensions, efficiency and lifetime) compatible with small devices mentioned below. The use of organic polymers allows the use of flexible substrates like plastic sheets. It would then reduce the size and weight of conventional solar batteries and avoid dangers related to glass substrates. Beside, organic materials to be used here are absolutely non-toxic molecules, in sharp contrast to materials used in today's batteries (lead, etc).

The self-rechargeable polymer solar battery is a new concept that would not only overcome problems but also open new markets. A battery recharging itself by just leaving it exposed to room or day light for a few hours or devices with its power supply open to illumination through a transparent window and thereby powering itself (e.g. in remote controls, electronic games, wireless headsets, wireless keyboards for computers, safety lights for bikes, electronic tags) might even one day replace most of primary and rechargeable batteries sold today.

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Annual Report 2004

SUNtool
A Sustainable Urban Neighborhood Modelling Tool

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Project- / Contract Number	EU NNE5-2001-753, OFES 02.0066
Duration of the Project (from – to)	January 2003 to December 2005

ABSTRACT

The project SUNtool (Sustainable Urban Neighborhood modelling tool) aims at elaborating a design tool for the urban planners, taking into account the criteria of sustainable development, and particularly the energy and resource flows. In particular, the renewable energy sources and the energy savings are considered.

The size of projects to be handled by the future tool can be anything between a small group of buildings and a whole urban area (maximum size considered should be around one km^2). A graphical user interface will allow the planners to enter the geometric data, and a smart building properties entry system will allow sensible default values, depending on building use, location and climate, and similar data, to be automatically chosen, with the possibility given to the tool user to override them.

The project has been started on January 2003. Its planned duration is 3 years, i.e. until December 2005. The tool version delivered by the project will be a "beta" version, ready for use by practitioners but with some space left for improvements.

The report for year 2003 presented rather in details the goals of the project, to which the interested reader should refer. In the present report, essentially the results of the year 2004, as well as the perspectives for year 2005, will be presented.

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Annual Report 2004

PVSAT2 - Intelligent Performance Check of PV System Operation Based on Satellite Data

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Project- / Contract Number	BBW Nr. 02.0236 , ENK5-CT-2002-00631
Duration of the Project (from – to)	November 2002 until November 2005

ABSTRACT

The PVSAT2 project is the followup of the EU-Joule 3-project PVSAT1, which was successfully concluded in 2001. A practical application was realised with Satwatch in Germany, where the solar irradiation data provided by the Meteosat satellite is used to predict the energy yield of PV systems. This allows the operator of the PV system to compare with the effectively produced energy yield and therefore to check the performance of its PV system. There are two main differences respectively novelties in PVSAT2 compared to PVSAT1: First, the accuracy of the irradiance calculation is improved by using reference values from ground measurements (the so called kriging method) and by changing to data of the new MSG satellite instead of the old Meteosat satellite. Second, energy production of the PV system is measured on site and sent to a central server which automatically checks the performance of the PV system by comparing this data with the calculated energy yield. In case of insufficient performance, a failure detection routine searches for possible malfunctions of the PV system and informs the operator. This performance check runs automatically and doesn't require regular personal support.

Therefore PVSAT2 will establish a low cost, reliable and easy-to-use performance check of photovoltaic systems. This will significantly increase the operational availability of PV systems and thus increased power production and income can be expected. Average cost reductions of about 2-5 % in both system maintenance and power production are expected. By introducing a unique two-way communication structure between the PV system and a central intelligent system, PVSAT2 provides a basis for a variety of management and control activities for production statistics, utilities information and later on also production forecast. In addition, PVSAT2 will help to open the renewable energy sector to new information and communication structures by introducing satellite-derived radiation data and new Information and Communication Technology (ICT)-based decision making techniques. This lets PVSAT2 contribute to a successful integration of PV into future energy distribution structures by increasing the value of information and - correspondingly - the energy efficiency.

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Annual Report 2004

Energy specific Solar Radiation Data from Meteosat Second Generation: The Heliosat-3 project

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Project- / Contract Number	ENK5-2000-00332
Duration of the Project (from – to)	2001 - 2005

ABSTRACT

Remote Sensing from satellites is a central issue in monitoring and forecasting the state of the earth's atmosphere. Geostationary satellites such as Meteosat provide cloud information in a high spatial and temporal resolution. Such satellites are therefore not only useful for weather forecasting, but also for the estimation of solar irradiance since the knowledge of the light reflected by clouds is the basis for the calculation of the transmitted light. Additionally an appropriate knowledge of atmospheric parameters involved in scattering and absorption of the sunlight is necessary for an accurate calculation of the solar irradiance.

An accurate estimation of the downward solar irradiance is not only of particular importance for the assessment of the radiative forcing of the climate system, but also absolutely necessary for an efficient planning and operation of solar energy systems. Within the EU funded HELIOSAT-3 project solar irradiance data with a high accuracy, a high spatial and temporal resolution and a large geographical coverage will be provided, using the enhanced capabilities of the new MSG satellite. The expected quality of the solar irradiance data will be a substantial improvement with respect to the available methods and will better match the needs of customers of the resulting products.

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Annual Report 2004

PV Catapult

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Project- / Contract Number	n° EU: 502775 (SES6) – Coordination Action
Duration of the Project (from – to)	01.12.2003 – 31.01.2006

ABSTRACT

The potential for the EU solar electricity (PV) industry to contribute to a clean energy system are enormous. However, a great co-ordinated effort is needed to ensure that the sector fully benefits from the expansion of the PV market. In PV Catapult industry consultants and research institutes work therefore together to give a boost to the EU solar energy.

The consortium aims to accelerate market development by means of various strategic actions. In the first step the strengths, weaknesses, opportunities and threats for the PV sector will be identified. The Consortium also aims to optimise the transfer process from the research laboratories to mass production. As the integrating of PV in buildings is a major market potential in Europe, the consortium will engage the construction industry to strengthen the PV market.

In this project new financial instruments will be exploited for the industry and the end-consumer to decrease the cost of PV. This will be done for different regions: the current EU-members, Newly Associated States and emerging/developing countries.

The simultaneously production of solar electricity and thermal energy (PVT) has the potential to reduce cost significantly. This project aims at bringing together all the key players in the R&D and industrial PVT field in Europe, to collect the knowledge, to structure it and to make it accessible. The gathering of key players will result in a strong network and have positive influence on the R&D effectiveness.

A grown up PV-marketed needs reliable standards and energy yield predications. To increase the understanding of the measurement of PV the same panels will be measured in different laboratories. This so called robin test will be made available to the PV community through a variety of means. Non EU-members are at the moment taking the lead for new standards, with the risk that EU interests are neglected. By exchange knowledge within the EU PV-community a good preparation for this process is made.

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Annual Report 2004

Schweizer Beitrag zum IEA PVPS Programm, Task 1

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Project- / Contract Number	11427 / 11058
Duration of the Project (from – to)	1.1.04 – 31.12.04

ABSTRACT

The Swiss contribution to the PVPS Task 1 Work Programme included:

- **National Survey Report**, a summary of developments in the market and political areas. The report's data is integrated into the IEA PVPS **International Survey Report**
- Acquisition of Swiss contributions to **PV Power**, distribution of the magazine to approx. 250 addresses in Switzerland
- Targeted search for **new contacts** in the PV area
- Contributions to 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 and December, including an article on the PV-house in Dottikon, Switzerland
- Two **Task 1 meetings** in Daejon, South Korea, and Port Macquarie, Australia

Work still to be done:

- To include more details of the PV value chain in the trends report 2004
- Organize a Workshop at the PV conference in Barcelona (June 2005)

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Annual Report 2004

IEA PVPS Programm, Task 2 (Schweizer Beitrag 2004)

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Project- / Contract Number	14805 / 151057
Duration of the Project (from – to)	1. January 2004 - 31. December 2004

ABSTRACT

Switzerland has committed itself to take part in the Photovoltaic Power Systems (PVPS) programme of the International Energy Agency (IEA), Task 2. The aims of the IEA-PVPS-Task 2 are outlined in the IEA PVPS Implementing Agreement of April 1994.

The overall objectives of the Task 2 is to provide technical information on operational performance, long-term reliability and sizing of PV-Systems to target groups.

Submissions have ben made to the Executive Committee of the IEA PVPS for the extension of Task 2 for another four years.

Subtask 1: Performance Database,
Subtask 2: Evaluation of Photovoltaic Power Systems (terminated in phase 2),
Subtask 3: Measuring and Monitoring (terminated in phase 1),
Subtask 4: Improving Photovoltaic Systems Performance (terminated in phase 2).

New activities:

Subtask 5: Technical Assessments and Technology Trends of PV Systems,
Subtask 6: PV System Cost over Time,
Subtask 7: Dissemination Activities.

The work of the Task work consists now mainly in the preparation and the dissemination of results to the target groups via the Task 2 homepage (http://www.iea-pvps-task2.org/).

This annual report gives an overview of the Task 2 main activities for the year 2004, mainly:

- IEA PVPS Performance Database
- Dissemination of results
- Implementation of new activities

Duration of Task 2 activities, phase III: 2004 to 2007

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

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Annual Report 2004

IEA PVPS Task 3 Use of photovoltaic systems in stand-alone and island applications

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Project- / Contract Number	35550 / 151123
Duration of the Project (from – to)	9/01 – 10/04

ABSTRACT

From Solar Home Systems (SHS) until large hybrid photovoltaic systems for rural electrification, IEA PVPS Task 3 main objective is to improve the reliability and cost effectiveness of PV systems in stand-alone application.

To reach these objectives, the task has been divided into the two main following categories:

- Subtask 1 : Quality insurance, schemes for improving the reliability, lower the cost and increase the lifetime of SAPV systems.
- Subtask 2: Technical issues, technical recommendations for cost reduction of systems.

The task has finished its program in mid 2004 and published two reports at the beginning of the year:
"Guidelines for Selecting Lead-Acid batteries used in Stand-Alone Photovoltaic Power systems " describes all the available technologies and compare their merits for storing PV electricity. A last part presents the grey energy of each technology and calculates the amount of grey energy that can be stored and drawn back from the batteries.
"Alternatives to lead-acid batteries in stand-alone PV power systems" presents twelve ways of storing electricity and compares their efficacy with lead-acid technology. This reports is useful for getting information on what is available today and what might become a real alternative to the LA batteries which is not at all a friendly environmental way of storing a renewable resource.

The last meeting in March 2004 was held in Ginostra on Stromboli island where a hybrid 110 kW photovoltaic / diesel stand-alone system started operation at the end of 2003. That visit demonstrated well that the future of stand-alone systems will more and more be in large projects to supply electricity to small communities and so creating what we call micro-grids. The main interest in studying SAPV system will be the design and optimization of such systems which for developing countries are often the only available alternative the extension of the grid.

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Annual Report 2004

Swiss Interdepartmental Platform for Renewable Energy Promotion in International Co-operation (REPIC)

including Swiss contribution to IEA PVPS Task 9

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Project- / Contract -Number	seco UR-00123.01.01
Duration of the Project (from – to)	March 2004 – February 2007

ABSTRACT

The Swiss State Secretariat for Economic Affairs (seco), the Swiss Agency for Development and Cooperation (SDC), the Swiss Agency for the Environment Forest and Landscape (SAEFL) and the Swiss Federal Office of Energy (SFOE) have founded a new interdepartmental platform for the promotion of renewable energy 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 co-operation are:

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

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

Under these goals, the REPIC-Platform also provides the Swiss contribution to IEA PVPS Task 9 - *Photovoltaic Services for Developing Countries.*

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Annual Report 2004

PV-NAS-NET

Coordination of Newly Associated States and EU RTD Programmes on Photovoltaic Solar Energy

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Project- / Contract Number	NNE5-2002-00046, BBW Nr. 02.0321
Duration of the Project (from – to)	01.01.2003 - 31.12.2004

ABSTRACT

The overall objective of the project is better coordination of science and technology activities in the sector of photovoltaics in the Newly Associated States* (NAS), thus integrating them into the European Research Area. The purpose of the project is to bring up a realistic picture of the achievements and failures in the PV field in 10 NAS: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.

The project PV-NAS-NET - the network of the representatives of ten Newly Associated States, four EU Member States (the Netherlands, Greece, Austria and Finland) and Switzerland is complementary to PV-EC-NET. It was created to increase the coherence of the PV RTD activities of the NAS and the EU and therefore to promote the development of Photovoltaic Solar Energy (PV) in NAS countries.

There are significant differences in the extent of PV RTD among the Newly Associated States and even more in comparison with those in the EU Member States. There is a need for identifying and overcoming existing barriers to the development of PV in these countries. The characteristics of the new enlarged European PV industry and the energy market require emphasis on technology transfer and dissemination, if new and improved energy technologies are to have the maximum impact. It is of strategic importance to have up-to-date information, to use the available results, to avoid mistakes made earlier by others, etc., and, if possible, to orient ongoing research activities towards the problems which are typical and important for both, the NAS and EU countries. PV-NAS-NET project aims at creating enhanced networking and coherence among PV RTD activities in NAS and EU countries in order to advance the above mentioned objectives in a coherent manner focussed on market, social and environmental needs.

The main goals of PV-NAS-NET are therefore:

- to improve the coherence of the NAS activities and European RTD programmes on PV energy;
- to formulate recommendations for PV RTD programming in NAS and the EC.

** Most Newly Associated States have become meanwhile Member States of the European Union. Reference of NAS remains for consistency in the project.*

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Annual Report 2004

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)

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Project- / Contract Number	CA-011814-PV ERA NET
Duration of the Project (from – to)	1 October 2004 – 30 September 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), which is considered a key technology and industry. The consortium comprises 17 participants from 11 countries with more than 20 national RTD programmes (or parts of programmes) and two regional RTD programmes.

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

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

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Annual Report 2004

Photovoltaic-Facade

Mounting system for thin-film-modules at facades

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Project- / Contract Number	100136 / 150169
Duration of the Project (from – to)	May 2003 – April 2005

ABSTRACT

Frameless thin-film-modules are interesting for façade application due to optical and financial issues. Within the Photovoltaic Façade project, the use of standard thin-film-modules has been investigated.

In 2004, investigations were made at the Lucerne Technical School of Engineering and Architecture. Investigations focused on the stress exerted on the modules and the fixations due to temperature differences caused by sunshine.

On the basis of the existing Aluhit mounting system several new profiles and mounting parts were developed. The new system can be used on concrete walls, masonry or metallic walls, and is an optimal solution for the façade integration of thin film modules.

A pilot installation is planned for 2005.

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Annual Report 2004

Photovoltaic-Alpur-Roof

New roofing-system for photovoltaic modules

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Project- / Contract Number	45134 / 85214
Duration of the Project (from – to)	May 2002 – December 2004

ABSTRACT

The project photovoltaic-alpur-roof is a new development in roofing system that allows for easy integration of photovoltaic modules in a sloped roof.

The photovoltaic laminate fixation structure is assembled on large insulation plates with roofing membrane, directly in the factory.

First, the prefabricated elements are placed on the wooden panel over the rafters. Then, the string cables are laid out. Finally, the photovoltaic laminates are connected and placed into the framework.

The roofing system was tested in rain and wind-like conditions at the Sursee Test and Research Institute. The system proved reliable under all weather conditions.

The Lucerne Technical School of Engineering and Architecture investigated the new roofing system's solidity which fulfills the Swiss Norm SIA160 (261) requirements. The element fixations also proved to be resistant.

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Annual Report 2004

Toiture photovoltaïque Freestyle de 5,5 kWp

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Project- / Contract Number	45795 / 85855
Duration of the Project (from – to)	July 2002 to February 2005

ABSTRACT

The roofing system Freestyle allows to cover a roof with a unglazed watertight photovoltaic system. The main system features are:

- aluminium profiles that fixed to the roof structure
- corrugated panels made of reinforced polyester, that plays the role of self-draining sub-roof
- half-finite PV laminated based on triple cell a-Si technology that are assembled on steel plates
- EPDM joints, inserted in the gullets of the aluminum profiles, are used for the fixation of the PV laminates on the aluminium profiles.

The pilot system has a full size of 160 m^2. The active solar area is 100m^2 for an installed STC power of 5,5 kW. The color « dark grey » (RAL 7016) of the plates was chosen by the architect and is well matched to the color of the photovoltaic cells. This shows the capability of the system to offer a maximal satisfaction as far as esthetics are concerned.

The system was put into service in mai 2003. Up to now, it was operating well without any breakdown. The measurements were taken from the 1st of July up to now. We have therfore more than 12 monthes of follow-up of system's operation.
The results are far better than expected. A conservative production value of 4'500 kWh was offered. From the 1st of July 2003 un to the 30th of June 2004, the real production was close to 5'400 kWh, wich is an excellent value, provided the rather unoptimized system tilt angle.

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Annual Report 2004

Flat roof integration CPT Solar

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Project- / Contract Number	100493 / 150604
Duration of the Project (from – to)	from August 2003 to December 2006

ABSTRACT

The goal of the project is to analyse the behaviour and the energy yield of a 15.36kWp PV system based on flexible triple-junction thin-film amorphous silicon modules incorporated into a flexible polyolefine (FPO) membrane which acts as a waterproofing system for a flat roof and, in particular, to verify in which order of magnitude the better thermal behaviour of a-Si technologies can compensate for losses due to the quasi-horizontal roof integration.

The installation has been integrated into the roof of the Centro Professionale di Trevano (CPT), located near the University of Applied Sciences of Southern Switzerland and came into operation on 5th December 2003.

The mechanical characteristics and the reliability of the flexible polyolefine membranes make them suitable for combination with flexible amorphous silicon triple-junction modules. The modules are laminated on the membrane which is laid directly on the roof. The membrane is joined to the roof structure by means of hot air welding and then mechanically fastened.

The thermal insulation does not allow a ventilation of the modules as usually required by crystalline silicon PV modules. This leads to a heating of the modules and consequently to changes in the operating PV parameters.

The temperature of the modules reaches 80°C, typically 40-45°C higher then the ambient temperature. Thus it reaches the level where the main degradation mechanism can be reversed.

The annual energy production (1070 kWh/kWp) is higher than that expected for the first year of exposure. The annual production of Unisolar a-Si PV modules incorporated into the waterproofing membrane inclined almost horizontally (3° east and 3° west) is comparable to that of a normal c-Si module plant in open-rack configuration tilted at 30°.

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Annual Report 2004

P+D Projekt 23.5 kWp PV Anlage Zollhof Kreuzlingen

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Project- / Contract Number	100477 / 150580
Duration of the Project (from – to)	15. Oktober 2003 – 31. März 2005

ABSTRACT

The objective of the photovoltaic project Zollhof Kreuzlingen/Konstanz was to build a PV power plant as a demonstration object including a display panel that indicates the principal operational data. In order to reach this objective, innovative photovoltaic technology was used and the plant was built in a distinctive place. This resulted in a cross-border project affecting a broad public base and which guarantees the use of photovoltaic components manufactured in the Lake Constance region.

The plant consists of two flat roof photovoltaic solar power plants at the Zollhof (custom building). Each installation consists of 3 units with a photovoltaic surface of 184 m^2 (132 solar panels and 6 AC inverters) with a maximum power of 23.1 kWp. The inverters are innovative (winner of the Innovation Prize of the Staffelstein Symposium 2003) and highly efficient.

The photovoltaic solar power plant has been connected to the power supply system on May 11th, 2004 and has produced 518 kWh/kWp during the period from June 1st until October 21st, 2004; showing the effectiveness of this photovoltaic solar power plant.

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Annual Report 2004

17.6 kW_p installation with thin-film modules on the flat roof at the CNB ETHZ building

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Project- / Contract Number	100176 / 150244
Duration of the Project (from – to)	June 2003 - December 2005

ABSTRACT

The CNB building of the Swiss Federal Institute of Technology (ETH), Zurich, is located downtown. The building has to be renovated and as a part of the renovation a new photovoltaic installation will be realized. The building is subject to the local historical monument preservation and protection codes.

Therefore, the PV modules, as well the fixations will be the same colour and installed as symmetrically as possible.
The installation will have a power of 17.6 kW peak and will consist of standard thin-film-modules.

A display in the new cafeteria will provide information on the installation's performance.
The mounting structure will be executed in early 2005 (together with the roof renovation work) and the project will be completed by end 2005.

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Annual Report 2004

62 kW-PV- installation

Flat roof- integration with PowerGuard-tiles

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Project- / Contract Number	100154 / 150169
Duration of the Project (from – to)	April 2003 – December 2004

ABSTRACT

The Trisa Electro AG has built a new logistic center in Triengen, Switzerland. A 62 kW photovoltaic installation is integrated in the flat roof of this industrial building.

In December 2003, the PV system was installed. The installation of the PV roof was very easy and could be completed in a very short time. The PV system was connected to the grid of the local power company at the end of January 2004. The installed PowerGuard Tiles consist of thermal insulation elements and frameless photovoltaic modules. A measurement and data acquisition system has been installed that measures temperatures, irradiation, power and energy.

The measurements show an excellent electrical power production and at the same time, energy requirements for heating and cooling are reduced. The reduction of energy for heating only occurs when the weather is dry.

An information display panel will be installed at the entrance of the logistic center in 2005.

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Annual Report 2004

Preparation and Realisation of the Test- and Pilot Installation SOLIGHT

New Light-Weight Flat Roof PV Module Mounting System

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Project- / Contract -Number	100116 / 150134
Duration of the Project (from – to)	2003 -2005

ABSTRACT

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

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

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

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Annual Report 2004

27 kWp Anlage Hünenberg Montagesystem Alustand Freizeit- und Sportgebäude Ehret

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Project- / Contract Number	47458 / 87541
Duration of the Project (from – to)	Dec 2002 - Jun 2004

ABSTRACT

The **AluStand ® -** mounting system is an advancement of the established AluTec – System (Mod. dép.) particularly for flatroof solarplants. **AluStand ®** exhibits the same main features as the AluTec - System:

- Easy project planning supported by the AluStand – Projecttool (Excel Worksheet) with statements about stability against wind power, snowload and about plant dimensions and costs
- Module mounting without use of any tools
- With the newly developed Clickfix System the same is possible with the AluTec CF profiles
- Very fast and thus cost effective mounting capability
- Exchangeability of every module of the plant for maintenance and repair

Project targets:

- Realisation of a photovoltaic plant on a new sport-building with an installed power of 27,225 kWp
- Evaluation of the economising of working time using the **AluStand ®** - system
- Testing of the resistance against wind power and snowload
- Verification of the useability of the new developed projecttool with statements about the optimization of roof load

The photovoltaic power plant was connected to grid on June 18, 2003. It is working as expected. The touchscreen-monitor is usable for public since early August 2003.

The project ends with the year 2004. Subsequently the results and conclusions of the project will shortly.be published in the final report

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Annual Report 2004

Solgreen Kraftwerk 1 Zürich

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Project- / Contract Number	42920 / 82869
Duration of the Project (from – to)	1st July 2001 – Summer 2006

ABSTRACT

The Pilot and Demonstration plant ”Solgreen Kraftwerk 1” in Zürich, was built in June 2001 and realised the results of the Development Project `Optimierung des Systems Solgreen` in practice. The Solgreen system permits the integration of photovoltaics on green flat roofs with considerable advantages.

The project aims to investigate and demonstrate the quality and durability of the developed construction by optimized assembling and material cost at the same time. First results were made under construction and operation of the new plant in 2001. Furthermore the interacting influences of roof vegetation and photovoltaic should be examined scientifically during a long period by an external expert.

Up to now no detailed findings can be published, because the cover of vegetation will be change in the next 2 or 4 years. But some of the mixtures of soil and certain seeds seems to suit better than others. Some of the plants grow only low ground and do not cover the solar laminates and interfere the energy production.

Parts of the construction is surrounded by soiled. In order to scale the risk of metal corrosion measurements has identified pH values. In Comparison with the material properties of zinc and aluminium no critical material-dependent corrosion has to be expected. As well visual inspection has shown no points at risk from corrosion.

On important goal of the Solgreen project is to inform a wide range of public about the aims und results of this project. Poster presentations at the National Photovoltaic Conference in Zürich und the 19th European Conference in Paris were great possibility to address specialists. A newspaper article were addressed to a lager scale of population.

In 2005 we will have detailed data on the changes and influence of the vegetation. And further data will support and give input to the data set today to come up with accurate results on the different factors.

Participants: Bau- und Wohngenossenschaft KraftWerk1, Enecolo AG, TISO, E. Schweizer AG, M. Maier, S. Brenneisen

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Annual Report 2004

Autonome Stromversorgung mit Photovoltaik und Brennstoffzellen

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Project- / Contract Number	47994 / 88095
Duration of the Project (from – to)	15.1.2003 – 31.12.2005

ABSTRACT

In 2004, the project „Autonomous Energy Supply by Photovoltaics and Fuel Cell“ had the following focus

- start of the operation of the fuel cell SFC 25 in the laboratory of the Swiss National Hydrological Survey (SNHS) of the Federal Office for Water and Geology (FOWG)
- measuring of the consumption and the performance of the fuel cell SFC 25
- installation of an autonomous energy supply with the fuel cell SFC 25
- analysis of the failures of the fuel cell SFC 25 / consultation of the producer to improve the model
- development of the improved and more powerful SFC A50-unit by the producer
- acquisition of the more powerful improved fuel cell model SFC A50
- preparation for the internal training with the producer and system supplier in spring 2005
- presentation at the PV exhibition in March 2004 at the Swiss Federal Institute of Technology Zurich

The main focus of the year 2004 was the preparation for the field test at the Swiss National Hydrological Survey (SNHS) of the Federal Office of Water and Geology (FOWG). It could be proven that the fuel cell is interesting for a compact monovalent autonomous power supply. During the test failures arose. From this reason, the more powerful improved SFC A50 model has been developed and procured. The tests will be continued at the beginning of 2005. In case of a positive result, the field test will be carried out at the sites evaluated in 2003.

The information activities have been continued. As expected, the interest has been remarkable. Nevertheless, the state of the art is not yet in line with the expectations. Practical experience with fuel cells in autonomous power supply installations is very helpful for consultations.

BFE OFEN UFE SFOE

Annual Report 2004

Monitoring of the CIS BIPV plant Würth in Choire

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Project- / Contract Number	47134 / 87254
Duration of the Project (from – to)	1st October 2002 to 31st September 2004

ABSTRACT

A new BIPV installation was concluded in October 2002 at the Würth Holding in Choire. The outstanding feature was the use of the synergies of new CIS BIPV modules. Those were special manufactured CIS modules, which had the task for producing energy and also to reduce the heat gain in the building by shading the skylights of the atrium. The goal was to get sufficient natural light and thus to safe the energy for artificial light during the daytime. Hence a combined concept was applied. On half of the skylights a fully automated roller blind was installed and on the other half the CIS specialised modules. For achieving the semi-transparency the layer of the CIS modules were removed in 1 cm strips, getting a 50% light gain. As each skylight has different measures different types of BIPV modules had to be manufactured. In total three dimensions but all with the identical operation voltage were manufactured and connected in parallel. This is resulting in a calculated PV peak power of 3.7 kW, which is being fed on a TopClass 4000/6 inverter and then to the building grid.

The project will monitor the performance of the modules and the PV plant over a period of 2 years. It is the goal to get many experiences, positive as well negative, and results with these special CIS modules. And also the influence of the BIPV plant in the building behaviour.

In 2004, the performance of the PV-plant has been analysed. The analysis of outdoor measured values at standard test conditions (STC) has shown an average module efficiency of 8.5 %. Furthermore module performance under lower irradiance shows a high energy yield.

For the measured data, the performance matrix of the plant in dependency of temperature and irradiance was derived from the TISO analysis methods for outdoor measurements. In 2003, first calculations have shown for the CIS Plant good results of power at STC. To detect all sorts of degradation, a new performance matrix for 2004 will be compared.

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Annual Report 2004

RESURGENCE

Renewable Energy Systems for Urban Regeneration in Cities of Europe

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Project- / Contract -Number	NNE5/00340/2001 BBW 01.0370-1/-2/-3
Duration of the Project (from – to)	Jan. 2002 – Dec. 2005

ABSTRACT

It is proposed to demonstrate the installation of 1.3MWp of photovoltaic in 5 countries as part of significant urban regeneration programmes. The four key project aims are photovoltaic system cost reduction, increased socio-economic acceptability and social sustainability, exploitation of liberalised electricity markets and finance innovation. The project targets the social housing / urban regeneration sector, other key objectives are to demonstrate innovative energy trading mechanisms, innovative PV system ownership models, and the exploitation of new capital investment mechanisms that exist for sustainable energy technologies.

Each country will demonstrate the use of PV as part of an integrated approach to urban regeneration. Partners have been drawn from all stakeholder sectors, including housing associations, housing networks, urban renewal companies, architects and engineers, building integration systems developers and installers, utilities and banks.

In 2004, some more PV-installations have been realised, especially in England, but also in Denmark.The German projects are still in behind due to the problem to find roofs in social housing where the Powerguard-system can be applied. An important part of the work has been social monitoring, where questionnaires have been sent to the tenants. Some of the questionnaires have already been analysed.

The goals for 2004 have not overall been achieved as especially in Germany and Denmark some installations still are not operating. They will be definitvely delayed as at least one year monitoring period is required. This will not be possible any more.

In 2005, monitoring, dissemination and social integration will be the main work tasks to be done. More informations on www.resurgence.info.

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Annual Report 2004

Campagne de mesures de l'installation autonome de 3,0 kWp à Soyhières (JU)

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Project- / Contract Number	100139 / 159172	
Duration of the Project (from – to)	June 2003 - December 2004	

ABSTRACT

The PV roof integration of the family Blattner in Soyhieres (JU) is one of the most important PV stand alone installations in Switzerland. This is a hybrid system using solar slates (Sunslates™) for the PV production, connected to a Diesel generator. The 3.0 kWp PV system is completely integrated in the roof annex of the farm. Mr. Blattner produces in this farm biological wine.

The system is operating since 1999 without interruption. The measurement campaign which started in July 2003 to end in October 2004, over a period of 15 months, has been made to control the behaviour of the system. It had the following main goals:

- *to optimise the system management, and more specifically the use of the Diesel engine, the set of batteries and other appliances ;*
- *to measure accurately the PV Sunslates™ system results and efficiency, with and without maximizer ;*
- *to precise technical and non technical limits for this kind application for stand-alone installation ;*
- *and finally to know the satisfactory degree of Blattner family after 5 years of use of the system.*

The analytic results of the present study are the following:

- *the PV system operates well since its setting up and it is correctly designed ;*
- *the solar covering ratio which measures the share of solar production in comparison with the total production of the system is around 76%, which enable to minimise the losses of solar overproduction ;*
- *the losses of the system proceed of the constraint of the battery cycling (daily partial charges and discharges of storage set that causes its heating) and of the life duration of the storage set, 50-70% already used, which decreases the performances ;*
- *the device to pursue the point of maximal power (MPP tracker) installed with one of the solar field do not bring any meaningful gain for the efficiency of the system.*

To optimise the installation, our unique proposal to improve the system is to opt for a different solution to manage the support engine “Diesel” in order to switch automatically from a PV production to a Diesel production (and vice versa) in function of the needs and the electrical production means, to limit at most the manipulations made by Mr. Blattner.

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Annual Report 2004

Messkampagne Wittigkofen

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Project- / Contract Number	100035 / 150040
Duration of the Project (from – to)	January 2003 – December 2005

ABSTRACT

In December 2000, a PV Façade was constructed on one of 5 high-rise apartment buildings, which are situated to the east of Bern. For a few reasons, the planned measuring system could not be completed. In collaboration with the owner of the PV installation, the Hostettler engineering company started a project in order to complete the measuring system.

The goals of this project are as follows:

- Obtain general experience on high PV Façades
- Obtain specialized experience on the influence of special measures for fire-protection
- Create a basis for the planning of high PV Façades
- Furnish information to the owner and to the public

Upon completion, the measuring system was operational at the end of April 2003. At first, data was directly obtained on site. After a modem change, a connection by phone-line was established at the end of November 2003. Also, a display for information was designed by a commercial artist and put into operation at the end of November 2003.

At the beginning of October 2004, the battery-support for the datalogger failed and had to be changed. Because of this reason, there is a little gap in the measured data.

Except for the modelling of the PV plant in the PVSYST software, all the planned work of this year have been completed. The modelling will be finished by spring 2005. Based on this, the evaluation of the first measuring period can then begin.

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Annual Report 2004

PV-ThinFilmTest

6 THIN-FILM TECHNOLOGIES IN 3 DIFFERENT BIPV MODES

COMPARED IN A REAL OUTDOOR PERFORMANCE TEST

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Project- / Contract -Number	45555 / 85617
Duration of the Project (from – to)	Sep 2002 – Dec 2004

ABSTRACT

In a worldwide probably unique large-scale thin-film test installation, 6 different thin-film PV technologies have been installed each in 3 different BIPV application modes on test installation in Switzerland. The total of more than 450 thin-film modules include a-Si and CIS technologies. Each module type has been installed in 3 modes: inclined (20°), flat with free back air flow, and flat with thermal back insulation. Behavior and performance of all market available different thin-film BIPV systems are observed with an extensive monitoring program, including I_{DC}, U_{DC}, and P_{AC}, module and ambient temperature, and insolation. Additionally, 3 installed mono-crystalline PV arrays allow direct comparison of upcoming thin-film technologies to well known cell types.

The modules under test include 1-layer amorphous silicon technology (Kaneka K58), 2-layer amorphous silicon technology (ASIOPAK SG30, BP850, Dunasolar DS40), 3-layer amorphous silicon technology (UniSolar US64), copper indium di-selenid technology (Shell Siemens Solar ST40) and a well-known mono-crystalline silicon technology (Shell Siemens Solar SM 110) for comparison.

The results of the monitoring program 2004 shows again the monthly different performance ratios between January and November, related to the performance ratio of the reference. It has been verified that the differences between thermal insulated modules and modules with free back air flow are in parts significant (like shown in the annual report 2003): Whereas three module types are more efficient with free back air flow (ST40, SG30, US64), one module type yields significantly the same (BP850) and two module types more energy (K58, DS40) with thermal insulation.

The operating behaviour of the module ST40 seems to be similar to that of crystalline Si-cells (SM110) unless that the performance ratio in 2004 is still about 5% to 10% higher than that of crystalline Si-cells, also during the winter half-year. The performance ratio of SG30 is in the same region of ST40. The others thin film modules show in 2004 if any an advantage in the hot summer months (till 5% higher performance ratio); for the rest of the year are the performance ratios definite less as the reference (till 20% less performance ratio).

The results presented here are provisional kind and must be in future confirmed by later conducted detailed evaluations. Detailed analysis are going to be presented in the final report, which will be available in spring 2005.

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Annual Report 2004

Monitoraggio dell'impianto PV da 100 kWp AET III a Riazzino

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Project- / Contract Number	43907 / 83947
Duration of the Project (from – to)	From 1.1.2002 to 31.12.2004

ABSTRACT

The 100 kW AET III grid connected PV plant, located in Riazzino, was constructed in 1992 by the TNC company on behalf of the Swiss Federal Office of Energy. In 2001 the plant had to be modernised. The old 100kW converter has been substituted by three new converters, 33kW each, and part of the wiring has been redone. The renovated PV plant was put into service on November the 30th 2001. Since then the AET has acquired this PV plant which has therefore been renamed AET III (originally Mark II). This project is intended to precisely monitor for 3 years the behaviour of the plant following renovation, by continuous and periodic annual measurements. The data acquisition system has been adapted to the new configuration and it was put back into operation at the beginning of 2002.

The behaviour of the plant has being yet analysed for 3 years: since the renovation the plant is working properly. Its PR now exceeds 70% (right from 65 W/m2), and it is better with respect to the one of previous years. Considering only the first 11th months of the year 2004, the plant has produced 101.963 MWh; this annual production exceed, for the second consecutive year, the limit of 100 MWh/a, never reached in the 11 previous years of operation (maximal production 98.5 MWh in 1999, average 93.5 MWh). This is due to the favourable meteorological conditions, but in particular to the excellent performances of the new converters. This energy yield (Yf_{2004}=975 kWh/kWp.y) clearly exceed the production estimation of 95-100 MWh. Since the PV plant was put into service in 1992, it produced 1'006,413 MWh, that corresponds to a total inverters operating time of 34'203 hours.

As observed since ever Box 1 strings produce more than those in Box 6. Nevertheless, all the 48 strings work properly. The 26 reference modules has been measured again at STC at the LEEE: their average power is 106.5 W, therefore the total estimated field power @STC is 92 kW. This value is still 11 % lower than that declared by the manufacturer. Moreover, another thermographic analysis of the entire plant has been carried out: a few hot spots were found but many of them have a high temperature (ΔT up to +30°C). One module with broken glass was replaced but incredibly the same module was found with broken glass again after few months. However the plant doesn't show any relevant or serious problem.

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Annual Report 2004

100 kWp PV-Netzverbundanlage A13 Messkampagne, Periode 2004

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Project- / Contract -Number	31883 / 150161
Duration of the Project (from – to)	January 2004 - December 2004

Abstract

15 years ago this 100 kWp PV-Plant built on top an existing sound-barrier structure along the A13 motorway in the Swiss Alps went into operation. At the time this project was unique, as it was the first PV-plant along a motorway worldwide and the largest PV-plant in Switzerland.

The purpose of this project is to gain information on the long-therm behaviour of a large gridconnected PV-plant and its components under real operating conditions. The monitoring and evaluation is carried out in accordance with the EU-Guidelines for PV Monitoring.

The plant produces on average 110'000 kWh per annum at a specific annual yield of 1'030 kWh/kWp. The plant operated for the first 10 years without any mayor interruptions. In the years 2000, 2001, 2003 and 2004 it suffered some mayor interruption due to inverter failure.

In November 2004 the now 15 year old 100 kW Siemens inverter was replaced with two modern Sputnik SolarMax 60 kW inverters.

Since November 2004 the plant is back in operation with 69 % of the modules connected.

In the period from June 2003 until December 2004 504 Modules were stolen from the plant in four seperate incidents.

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

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Annual Report 2004

Integration der neuen IEC 60364-7-712 in die nationalen Installationsnormen (NIN)

Niederspannungs-Installations-Norm, Technische Norm des SEV: SN SEV 1000:2000 Teil 7.12: Solar- Photovoltaik (PV) Stromversorgungssysteme

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Project- / Contract Number	100187 / 150258
Duration of the Project (from – to)	1. Juni 2003 bis 31. Mai 2004

ABSTRACT

In Switzerland, phototvoltaics also need practice-friendly installation standards for safety and increased application. A well applicable installation standard helps to prevent electrical accidents and damages to property (fire). Switzerland, as an IEC- and CENELEC-member, must adopt the new standard IEC 60364-7-712.

The existing provisional national PV-safety regulation from 1990 has to be adapted to the current standards of IEC and CENELEC. Important technical and national application rules, which are not regulated in the standards, have to be integrated or attached, e.g. lightning protection, potential equalization, main connection conditions and law requirements and, they are to be completed with important references. The new PV standard will be written for a widespread application and easy to apply for both installers and PV-experts. On one hand, PV experts are not very familiar with the general installation rules and, on the other hand, installers of low voltage installations are not really acquainted with the specific technology of PV systems. The core group has worked out the basic document. An enlarged group of experts secured broad support, and during a workshop, the PV-branch was given the opportunity to express its opinion. The new standard was well received.

The project is completed and the document is available in German and will soon be published in Italian and French.

BFE OFEN UFE SFOE

Annual Report 2004

GISS Gebäude-Integrierte Solarstrom-Systeme

(Building Integrated Photovoltaic BIPV)

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Project- / Contract Number	100141 / 150173
Duration of the Project (from – to)	Juni 2003 – Mai 2004 (Dez. 2004)

ABSTRACT

Supported by several sponsors, the SZFF is launching a widely-based research project enquiring into the potential for breaking down existing technical obstacles and mental hurdles between façade constructors and solar specialists; reducing the lack of information in the market; generation of BIPV-Projects in the fields of new building and conversions and raising the level of the technological expertise of façade constuctors in dealing with solar components in building envelopment.
Previous studies have shown that photoelectric panels can easily be installed by façade constructors. Technical communication between façade constructors and “photoelectricians” must be furthered and simplified. The future of BIPV depends on the increase in the use of photoelectrics in building projects. Most important are the interfaces between Façade Planners/Photoelectric Planners as well as both façade and photoelectric industrialists at their joint involvement in the planning of buildings. Multifunctional, integrated concepts of in-house technology in conjunction with the incorporation of photoelectric installations in façades have an enormous innovative potential

BFE OFEN UFE SFOE

Annual Report 2004

Solar *Electri*City Guide - Publikation „Solarstrom in der Gemeinde“

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Project- / Contract -Number	100627 / 150824
Duration of the Project (from – to)	01.07.2003 - 30.06.2005

ABSTRACT

Introduction:
The Swiss Solar Electri City Guide is a follow-up activity of the European project “PV City Guide” supported by the Swiss Federal Office for Education and Science under contract no BBW 99.0569. The European project was finalised in 2002. The country-specific Swiss editions are supported within the frame of the SwissEnergy programme.

Purpose of the work:
The objective of this Solar ElectriCity Guide is to provide local and regional authorities as well as related professionals (urban designers and developers, project developers and builders) an insight into the diversity of activities in the field of photovoltaics as well as information and instruments to set up and / or optimise activities in order to facilitate and enable the implementation of photovoltaics on the local level.

Approach:
The Swiss Solar ElectriCity Guide is being designed for practical use by the target groups in order to facilitate the implementation of future PV projects and policies. The international version of the Solar Electri City Guide in English has been adapted to the Swiss context in close relationship with experts and actors from different areas and sectors in order to consider local needs, actions and policies.

Results:
The project “PV City Guide” led to an attractive guide for the target audience. Some national and international Solar ElectriCity Guides have been published. The Swiss editions in German, French and Italian are being published.

BFE OFEN UFE SFOE

Annual Report 2004

IEC Normenarbeit für PV Systeme

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Project- / Contract -Number	DIS 17967/57555
Duration of the Project (from – to)	2002-2004

ABSTRACT

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

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

Work program: TC 82 has six active working groups developing standards for the photovoltaic industry. Some of the 20 current work program topics include: design qualification and type approval of solar modules, Solar Home Systems, safety of inverters and charge controllers, islanding prevention measures for grid connected PV Systems, and utility requirements for grid inverters. An eighth group under the administrative lead of TC 82 is a Joint Coordination Group with TC 21, TC 88 and TC 105 which is developing a series of 10 new standards dealing with various aspects of renewable energy system integration and project management.

Swiss interest and contribution: Switzerland, once a leading pioneer in grid connected PV systems, has in spite of shrinking federal budgets the on-going programme “Energie Schweiz”. The market, however, is mainly driven by green pricing, which provides a limited market volume of about 1 to 1.5MW/a. There are several Suisse mfg for plugs, grid connected inverters, stand-alone inverters, installation alu-profiles to facilitate mounting of PV modules and laminates, and turn key operators as well as many consulting and engineering companies, active both in Switzerland and abroad. Next to a direct involvement in the IEC work, all relevant documents are discussed in detail in the national standard committee TK82, in order to formulate Switzerland’s interest in adequate, simple and effective standards for PV. There are particular interests of the leading plug mfg to elaborate more specific standards for plugs in PV array cabling. Initial work has been discussed at Swiss national committee level.

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Annual Report 2004

Swiss Photovoltaic Internet Portal www.photovoltaic.ch

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Project- / Contract Number	39490 / 79286
Duration of the Project (from – to)	1.9.2000 – 31.3.2004

ABSTRACT

The main goal of the new Swiss photovoltaic website www.photovoltaic.ch is to provide comprehensive information about national and international PV activities to a target audience with specific interest in this matter.

The site delivers detailed information about photovoltaics in Switzerland from a public authority perspective, namely the Swiss photovoltaic programme (including all annual and final reports of individual projects), the IEA PVPS Programme, information concerning the market development of PV, activities of public institutions, as well as of many national and international organisations, including the corresponding links etc.
The whole website is designed to be user-friendly and features pictures, graphs and diagrams, making the content easy to understand.

Since autumn 2003, the German version of the site is fully operational. During 2005, an English and a French version will follow.

BFE OFEN UFE SFOE

Annual Report 2004

Photovoltaic Energy Statistics of Switzerland 2004

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Project- / Contract Number			
Duration of the Project (from – to)			

ABSTRACT

The project reported on in this paper is the follow up work of 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. The work carried out has revealed key figures for both PV performance and overall electric energy contribution of PV in Switzerland.

In 2004, 100 new PV plants were connected to the grid in Switzerland; 25 more than last year. The Swiss PV Market's installed peak power remained the same in 2004. This is in contrast to the world wide development, where the market of this future technology grows at a rapid pace.

Due to a 5% higher irradiation in 2004, compared to that of the last 20 years, the annual yield of all PV installations in Switzerland reached 815 kWh/kWp, slightly greater than the annual rate of about 800 kWh/kWp. The systems overall reliability and operational availability is still considered very good for such technical systems.

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Annual Report 2004

Solarstrom vom EW

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Project- / Contract Number	17067 / 73481
Duration of the Project (from – to)	from 1996

ABSTRACT

"Solar electricity from the utility" is the name of an action within the Swiss National Action Programme SwissEnergy, aimed at providing customers of utilities with the service of solar electricity. The action is supported by SwissEnergy since 1996. The fundamentals of the action can be described as a marketing approach towards both utilities and their customers in order to deploy the market for solar electricity for customers willing to buy this product at generation costs. After eight years of operation, this action has achieved remarkable results: More than 150 utilities participate in the action in the year 2004, more than half of the Swiss population now has access to this service, more than 6 MWp of photovoltaic power systems have been installed within this concept and more than 5.6 GWh of electricity are subscribed annually. The growth in the market has declined, as other products (power out of water, wind or a mix of renewables), have been launched.

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