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Photovoltaic Programme Edition 2004

Summary Report, Project List,
Annual Project Reports 2003 (Abstracts)

elaborated by:
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Title photo:

5.5 kWp Freestyle® roof integration with thin cell modules in Lutry near Lausanne

(Photo: Solstis)

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Photovoltaic Programme Edition 2004

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PHOTOVOLTAICS

Summary Report – 2004 Edition

Reporting period 2003

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Industrial plasma deposition plant

Unaxis is building a plasma deposition unit for the industrial fabrication of micromorph solar cells using the method developed by the IMT at the University of Neuchâtel. By exploiting synergy effects from other processes, a rapid transfer of technology should be achieved.

(Photo: Unaxis)

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1. Programme priorities and targets for 2003

The photovoltaics (PV) programme was characterized in 2003 by further consolidation of its implementation oriented activities. These were intensified firstly through new cooperation projects with industry, and secondly via international cooperation. Despite the stagnating national market and the discussion centering on the future of SwissEnergy, when regarded from a technological viewpoint, growing interest on the part of industry may be identified. Thus the industrial basis has continued to expand. The programme has also maintained a pronounced international bias. In the period covered by this report, a total of some 85 research and development (R+D) and pilot and demonstration (P+D) projects were in progress. This figure includes all identified projects benefiting from public funding. The number of projects and the volume of funding were of the same order as last year.

The Photovoltaics Research Programme 2000-2003 [90], approved by the Federal Energy Research Commission CORE, is divided into the following sections:

Solar cells for the future

The work on **thin film solar cells** focused on **silicon** (amorphous, microcrystalline) cells, cells based on **compound semiconductors** (CIGS) and **dye cells**. New production processes have emerged particularly in the case of thin film silicon cells. Implementation efforts continued in all technologies, and several important new projects were set out in collaboration with private companies.

Modules and building integration

The **integration of photovoltaics** in the built environment continued to be the main concern of current applications. At present, the emphasis is on products for building integration of thin film solar cells and on the experience to be gained from these. New industrial processes for solar modules, as well as opportunities for optimising these to achieve further cost reductions, were studied.

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. Determined efforts were made during the report period to obtain reliable predictions of the **energy yield** of solar modules. The **standards** for installing grid coupled PV installations were out of date and had to be revised. For **island installations**, storage design and the combination of photovoltaics with other energy technologies are subjects of relevance.

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 the mainstay 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. Cooperation at international level was successfully extended during the report period. In this way, a strong involvement of Swiss photovoltaics in international endeavors at the scientific and technical levels could be assured.

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. A range of fundamental work was carried out within the ETH Council's *TOP NANO 21* programme. Moreover, the industrial projects were further pursued with the support of the CTI. The continuing success of Switzerland's participation in EU projects underlines the international competitiveness of her solar cell research.

Thin film silicon

During the report period, IMT at the University of Neuchâtel embarked on the latest phase of the **micromorph solar cells** [1] project. This may be regarded in the following respects as an important transitional development: (a) begin of intensive co-operation with the Unaxis company, which is setting up an industrial-scale laboratory for solar cell deposition units, for which it has created its own commercial subsidiary, *Unaxis solar*, in Neuchâtel [91]; (b) change of personnel, accompanied by the appointment of Prof. A. Shah's successor as head of the research group; and (c) the future short and middle term research orientation. The emphasis within this SFOE project will be on the key factors assuring IMT's prominent research standing in the field of thin film silicon. These concern the deposition speed of microcrystalline silicon, the optical absorption of this material, and transparent oxide films (TCO) for optimum light scattering. Cooperation on solar cells on plastic substrates with the spin-off company VHF technologies was intensified. The results in the various areas of work can be summarized as follows. The deposition rate of microcrystalline silicon in solar cell quality was increased to over 2.5 nm/s. Single cells of microcrystalline silicon on glass attained 7% efficiency at moderate deposition rates. Efficiencies of 7% were achieved for amorphous and 5.2% for microcrystalline silicon on PET plastics (n-i-p single cells), an encouraging result for this new material combination. Moreover, new procedures for structuring the substrate were introduced. At a more fundamental level, the growth and structure of microcrystalline silicon was studied. This work received an award at the 3rd World Conference on Photovoltaics in Osaka [92]. The EU **DOIT** [2] project to extend work on micromorph solar cells was completed during the report period. The overall objective was to produce a small micromorph model measuring 30x30 cm² with a stable efficiency of 11%. IMT's main task in this connection was to achieve large-area deposition by means of VHF. Problems with the reactor attributable to oxygen contamination were encountered over the report period, and these led to substantial delays. It was therefore not possible to achieve the target of 7-8%, the best provisional result being 5.3%. Nevertheless, an overall stable efficiency of 10% was achieved in the project.

In the above mentioned industrial project with Unaxis, the KAI deposition units used for the production of large-area flat-screen monitors (Fig. 1) are to be optimised for the production of micromorph solar cells. This project is a very ambitious industrial endeavour that could revolutionize the production of thin film solar cells.

The joint CTI project on the **rapid large area deposition facility** [3] for thin film silicon solar cells between the CRPP at EPFL, IMT and Unaxis, was completed during the report period. Based on a single chamber system of 1.4x0.7 m² area, all the project objectives relevant to the production of a stable amorphous p-i-n solar cell were achieved at a deposition rate of 3 Å/s. The project represents an important facet of the transfer of technology to Unaxis mentioned above.



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

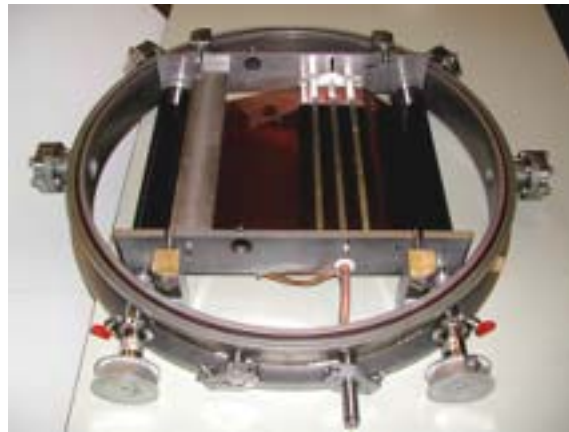


Figure 2: Test facility for roughening of polyimide films (Photo: EIAJ)

The project at the University of Applied Sciences in Le Locle (EIAJ) in cooperation with VHF Technologies on efficient light trapping by means of controlled **roughening of polymer substrates** [4] was completed during the report period. The process involves reactive ion etching using SF_6/O_2 on a roll-to-roll basis to roughen the substrate (Fig. 2) to augment light trapping, thereby raising the efficiency of the amorphous solar cells. With this, the roughness of the polyimide substrate could be adjusted at will, enabling the efficiency to be increased by 10%. In combination with amorphous silicon, the modified substrate achieved an initial efficiency of 6.9% at IMT. In a *TOP NANO 21* project, the production of **nano structures on polymer substrates** [5] for improved light trapping was studied in collaboration with VHF Technologies. This will be based on reactive ion etching and aluminium deposition. Experiments were performed both with amorphous and nanocrystalline silicon films. Fundamental work both on aluminium diffusion and aluminium-induced crystallization processes was performed.

The objective of the new project at VHF Technologies [6] is to improve the **reliability of amorphous solar cells on polymer substrates**. Central to this work is to improve the adhesion of the metallic back contact to polyimide. By determined optimisation of the process, a significant improvement in the adhesion properties was soon achieved, resulting in improved performance under thermal cycling.

Crystalline silicon

HCT Shaping Systems is engaged in the EU **RE-SI-CLE** [7] project to develop new processes to extract the silicon base material from silicon waste for reuse in the production process. This is desirable in order to conserve the scarce raw material needed for the production of crystalline silicon solar cells. At present, 34% of the silicon used for these is lost in the form of silicon dust, amounting to 5.1 tonnes of silicon per MWp of modules produced. Based on an analysis of the slurry from the slicing saw, suitable mechanical and chemical extraction technologies are to be identified and developed (Fig. 3).

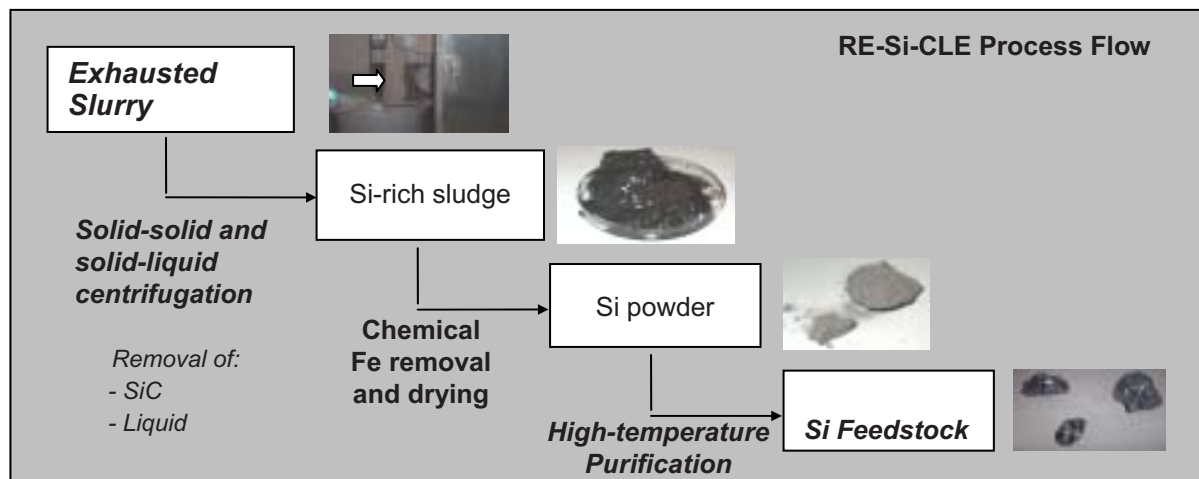


Figure 3: Process sequence for recycling silicon (Photo: HCT Shaping Systems)

II-VI composites (CIGS)

The thin film physics group at ETH Zurich has been working on EU projects involving solar cells based on compound semiconductors (CIGS, CdTe) for many years now. The EU **PROCIS** [8] project was completed during the report period. The project was successful in developing production techniques for larger-area CIGS cells. To do so, the incorporation of sodium, which is known to have a favourable influence on the growth kinetics and microstructure of the CIGS films, was studied. CIGS solar cells with buffer films were produced using various vacuum processes. CdS buffer films produced by wet chemical processes (14-15% efficiency) perform significantly better than vapour-deposited films (10-12% efficiency). The results with ZnS and ZnSe films proved less satisfactory (approx. 9% efficiency). The subject of new buffer films for CIGS solar cells is being further studied in the EU **NEBULES** [9] project. In this, the group is concentrating on the structural and electronic properties of solar cells. The studies performed to-date have provided a better understanding of the interfaces, enabling the differences between the various processes mentioned above to be characterized. Furthermore, buffer films of In_2S_3 are being studied. With these, the project partners achieved an efficiency of 16.4%. The objective of the EU **METAFLEX** [10] project is to develop a roll-to-roll production process for flexible CIGS solar cells. For these, the ETHZ research group is focusing on CIGS deposition on polyimide, minimodules, and CIGS deposition at temperatures below 450°C. The emphasis during the report period was on the production of polyimide substrates by spin coating. Based on the success obtained with other substrates, sodium was incorporated in the CIGS film, for which a special method is now being developed. Till now, efficiencies up to 14.4% were obtained.

In a *TOP NANO 21* project, novel techniques for producing CIGS cells using **nano materials** [11] are being sought. In non-vacuum processes, cost reductions may be obtained by the use of suitable precursor films. The precursor film is sintered in a selenium atmosphere. An efficiency of 6.7% calculated from the current-voltage characteristic was achieved during the report period.

Dye cells

At ICMB at EPF Lausanne, the development of dye-sensitised, **nanocrystalline solar cells** [12] was pursued during the report period. Dye synthesis was further developed in order to increase the useful temperature range. In the *TOP NANO 21* project, **indoor applications** of dye cells [13] are under development in cooperation with Greatcell Solar. In a further *TOP NANO 21* project, **flexible dye cells** [14] are being studied. Attention is focusing here on substrates of stainless steel foils.

In the EU **NANOMAX** [15] project, alternative types of dye-sensitised solar cells involving new photo-electrode designs and materials, new dyes, enhanced transport properties and reduced recombination of the charge carriers are being studied. With these, it is hoped to achieve an efficiency of 12%, with a possible improvement to 15% (or to 9% over an area of 100 cm²). The EPFL research group is concentrating on different variants of the dyes employed.

Antenna solar cells

Fundamental work continued at the University of Bern under the solar chemistry programme on **antenna solar cells** [16], with the financial assistance of the Swiss National Science Foundation. The objective is to develop a new type of dye-sensitised 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.

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 utilized in the context of installations operating within 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), work is increasingly concentrating on the solar modules themselves. Attention is also turning to the conditions necessary for successful integration of thin film solar cells and the development of suitable systems. Swiss companies are presently engaged in a range of new EU projects for these.

The CTI project to develop a **PV composite module** [17], in which VHF-Technologies and Alcan Technology & Management are collaborating with University of Technology in Le Locle (EIAJ), was completed during the report period. The project objective was to develop a solar module suitable for building integrated applications based on *Alucobond*[®] and VHF Technologies’ amorphous silicon solar cell. A manufacturing process for large-area modules, together with the necessary lamination technology, was established. The stable efficiency was increased to 4%, and an initial series of prototype modules produced and tested in an outdoor facility (Fig. 4).



Figure 4: Initial solar module prototypes based on *Alucobond*[®] and VHF Technologies’ amorphous silicon solar cell being tested at the University of Applied Sciences in Le Locle (photo: EIAJ)



Figure 5: Outdoor demonstration facility for testing CIS elements in the HIPERB project (photo: 3S)

Swiss Sustainable Systems (3S) are studying the potential increase in performance of solar modules using **reflection-free glass produced by surface etching** [18]. Initial tests with normal and etched glass confirmed the feasibility of this. The company is also participating in several EU projects on PV

building integration. The EU **HIPERB** [19] project concerning the application of CIGS cells to photovoltaic roof and facade systems was completed during the report period (Fig. 5). At the same time, the *Megaslate*[®] systems are being further developed. A number of building integrated test structures were built, and these are being tested with a view to obtaining TÜV certification. In the EU **AFRODITE** [20] project, esthetically appealing systems for PV building integration are being developed using back-contacted crystalline cells. These are now being prepared for series production, whereby 3S has been concentrating on optimising the cell circuitry.

Kurth Glas & Spiegel was engaged in the EU **ADVANTAGE** [21] project, which was completed during the report period. Efforts were directed to the development of solar modules with printed circuits applied to glass, i.e. to modules not using EVA. The focus of this work was on improving the contact between the solar cell and the printed circuit. However, since the required back-contacted solar cells were not available in time, their use in the glass modules could not be tested.

Alcan Packaging continued its work in the EU **HIPROLOCO** [42] project, in which new and inexpensive techniques for encapsulating solar cells in modules were developed.

The **DEMOSITE** [22] project at the ETH in Lausanne was put on standby for possible further use. The facility displays numerous variations of systems for building integration of photovoltaics in flat roofs, gable roofs and facades. The project may be virtually visited in internet (www.demosite.ch), where professional information for interested architects and other specialists may be found. Work during the report period concentrated on maintaining the facility, developing the website and guidance for visitors.

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-term monitoring). Particularly in the current phase of rapid market growth, the experience gained from these application-related studies is vital to ensure the safety and reliability of future installations and the standardization of products. There was an acute need for action on the standardization and associated quality assurance of photovoltaics systems installation. This is also the case for building integration components, for which no valid standards are available despite the growing market.

The LEEE-TISO Institute of SUPSI completed the project on **quality assurance and energy yield of photovoltaic modules** [22] during the report period. The ninth test cycle on a total of 14 solar modules (3 sc-Si, 9 mc-Si, 2 a-Si) was completed (Fig. 6). The drop in performance of crystalline solar modules amounted on average to -3.2% in the first 9 months of operation, confirming previous observations. The laboratory, which is certified for measurements on the class A solar simulator under ISO 17025, is subject to an annual audit, and this has resulted in an increase in precision. During the report period, around 1500 I-V characteristic curves were measured, 348 of these for commercial customers. LEEE-TISO is participating in a worldwide 'round robin' solar module test with 9 other laboratories, which will continue until 2005. Measurements continued on the 3 photovoltaic installations. Work on the 20 year old 10 kWp installation in the joint EU **MTBF-PV** [23] project, in which LEEE-TISO and the European Test Laboratory at Ispra collaborated, was completed during the report period. An increasing number of modules (2003: 24 modules – 9.5% of the total number) showed delamination of the tedlar film from the rear aluminium film. This question must be further pursued to reduce capacitive coupling and improve electrical safety. Following 12 years of service, the power inverter is now in need of replacement, for which 3 new phase power inverters for each of the 3 module fields are recommended.



Figure 6: TISO PV module test stand
(Photo: LEEE-TISO)

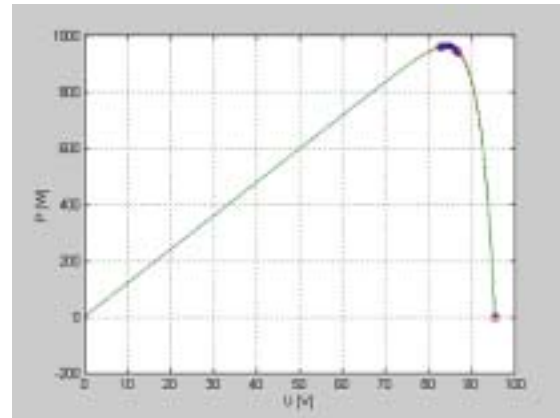


Figure 7: Automatic determination of the power inverter maximum power points MPP (Photo: HTI Burgdorf)

LEEE-TISO is also participating in the EU **PV Enlargement** [25] demonstration project in 10 European countries, 5 of which are in Eastern Europe, comprising 32 installations with a total capacity of 1.15 MWp. LEEE-TISO is responsible for scientific consulting, particularly concerning calibration and performance measurements on the solar modules. Tests are to be performed on 210 randomly chosen solar modules.

The project on **long-term behaviour of grid-coupled photovoltaic installations** [26] at the photovoltaics laboratory of the University of Applied Sciences in Burgdorf with the support of the Mont Soleil Association, Localnet, Elektra Baselland and the SFOE was completed. In the project, 42 installations with 55 power inverters were measured. The excellent reliability of the power inverters was again confirmed during the report period. The energy yield of the 560 kWp installation in 2003 was 1135 kWh/kWp as against 935 kWh/kWp in 2002. The photovoltaic installation on the Jungfrau-joch in the High Alps celebrated its 10th anniversary, with an average energy yield over the 10-year period of 1372 kWh/kWp. Data for selected installations are converted to the IEA PVPS Task 2 database format [37]. This extensive collection of data on the operating characteristics of a large number of very different installations is now available to the scientific community, and may partly be accessed online via www.pvtest.ch. The work is to be continued under the successor project, **photovoltaics systems technology PVSYTE** [27]. The control software for the 25 kW photovoltaic generator simulator was updated during the report period, so that semi-automatic tests on power inverters can now be made. In particular, automatic maximum power point (MPP) measurements are now possible (Fig. 7).

Enecolo participated in the project concerning the **energy yield of solar modules** [28] with partners in Switzerland and abroad. The procedure is based on the modules' performance matrix (Fig. 8). In the project, a number of experimental methods were compared and evaluated. The PSI method involving the determination of MPP performance in conjunction with six other variables has proved particularly effective.

Dynatex participated in the EU **INVESTIRE** [29] project, which was completed during the report period. Nineteen further companies and 15 research laboratories were engaged in evaluating a range of storage technologies for renewable energies, particularly for photovoltaic island installations. The 9 storage technologies comprised the principal types of battery (lead, lithium, nickel, metal-air) and alternative storage techniques (supercaps, electrolysis/hydrogen/fuel cell, flywheel, compressed air, Redox systems). The characteristic technical and economic parameters of these were brought together in a form permitting comparison – a unique and comprehensive set of data. The results show that for economic reasons, replacement of the lead accumulator will be no easy task where primary applications are involved. The only promising alternative is to use compressed air.

Solaronix is participating in the new EU **EURO-PSB** [30] project to develop a polymer solar battery. This is a small, self-charging, battery for mobile applications (Fig. 9). The principle lies in combining a novel polymer solar cell (organic solar cell) with a rechargeable polymer battery.

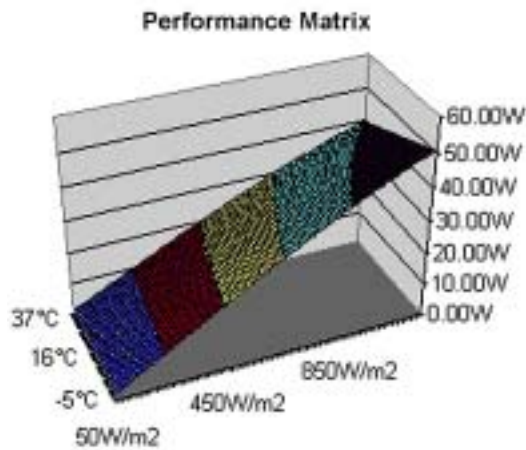


Figure 8: Performance matrix of a solar module
(Photo: Enecolo)



Figure 9: Application of the polymer solar battery
(Photo: Varta)

FURTHER PROJECTS AND STUDIES

ESU Services is participating in the EU **ECLIPSE** [31] project, in which consistent, easily accessible, and up-to-date life-cycle data for use in present-day and future European energy systems were prepared. The data set is designed to be adaptable to local conditions and facilitate technical improvements. It includes the following new non-centralized technologies: photovoltaics, wind energy, biomass power stations, decentralized CHP (fueled with natural gas and biomass) and fuel cells (for natural gas, hydrogen or biogas). In the case of the photovoltaic systems, the data were taken from the „ecoinvent 2000“ [93] project.

The LESO laboratory of the EPF Lausanne is participating in the new EU **SUNtool** [32] project, embodying a modelling tool for the urban environment. Typical applications are to analyze the energy and material flows in a group of buildings or entire urban district (< 1 km²). The tool is based on comprehensive analytical models of the different technical aspects, which will eventually be combined in a single graphical user interface.

Enecolo is participating in the EU **PVSAT2** [33] successor project. In this, satellite-based performance monitoring is to be further developed, firstly by the application of more precise data available from satellites, and secondly by providing a central database for PV production data. In general, the system should provide a reliable and economic means of monitoring photovoltaic installations.

The CUEPE at the University of Geneva is engaged in the EU **Heliosat 3** [34] project to determine the specific energy content of solar radiation based on Meteosat data. The MSG (Meteosat second generation) satellite (<http://www.esa.int/msg/>) will be used in the project. The new satellite should provide more precise radiation data.

The University of Zurich participated in the EU **MSG: Multi-user solar hybrid grids** [35] project, which was completed during the report period. In this, attention focused on the social and scientific aspects of solar electricity generation in villages remote from the grid. A simulation model was developed to describe the social behaviour of the users of these installations, and was coupled to the technical model. Initial simulations were performed with the combined model.

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). Switzerland also continued to chair this international programme during 2003. Directly following on from the third World Photovoltaics Conference in May, an international conference [95] was successfully organized to mark the 10th anniversary of the IEA PVPS programme. The programme is to continue its endeavours based on a revised strategy. Detailed information on its activities and data can be found on the www.iea-pvps.org website.

In IEA PVPS Task 1, which is concerned with general **information work** [33], Switzerland is represented by Nova Energie. A further national report on the photovoltaics activities in Switzerland up to 2002 [96] was prepared during the report period. This formed the basis of the 8th annual international report (Fig. 10) on market developments in photovoltaics in IEA countries [97]. This international publication has established itself as a widely cited reference on developments and trends in the photovoltaics markets of IEA countries. The *IEA PVPS Newsletter* [98] 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** [37]. The *PVPS Performance Database* [99] was enlarged to include new data, and now covers 370 photovoltaic installations in 13 countries, involving almost 11 000 monthly data values and 11.8 MWp of installed capacity. The database has met with active interest, and has been delivered to over 1600 customers in 62 countries. The database is being applied to analyse specific aspects (e.g. radiation data, performance, shading and temperature effects, reliability in operation) in depth. The results of the analyses are to be published in report form.

Dynatex is participating in the work of IEA PVPS Task 3 on **island installations** [38]. 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. In 2003, reports on monitoring, protection against lightning, quality management and demand side management of island installations were published [100-104].



Figure 10: IEA PVPS International Survey Report

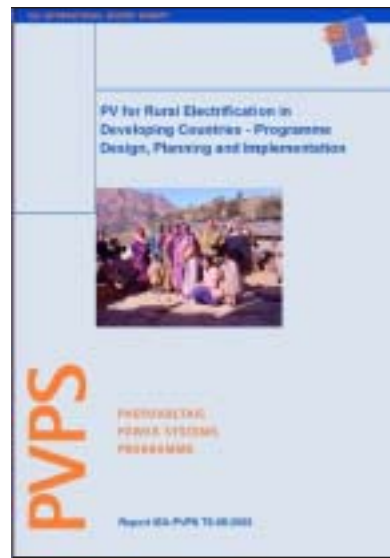


Figure 11: IEA PVPS Task 9 Report

The final report on power inverter types and safety equipment [105] was published under the IEA PVPS Task 5 project on technical aspects of grid coupling, which had been completed the previous year. The collected reports and results are available on CD-ROM [106].

With the support of the State Secretariat for Economic Affairs (seco), Entec is responsible for the Swiss contribution to IEA PVPS Task 9 on **photovoltaics development cooperation** [39], which forms part of the *PV EZA* platform for development cooperation in photovoltaic projects. Switzerland is responsible in this project for coordination with bilateral and multilateral organizations. In the report period, a range of new reports (Fig. 11) were published within the project on non-technical aspects of projects and programmes [107-113].

In conjunction with other activities under the PV EZA platform, Swiss participation in IEA PVPS Task 9 is helping to strengthen the uptake of Swiss know-how and products in international projects. In addition, the facilities of the multinational organizations – particularly the GEF (Global Environmental Facility) – are to be further exploited. A corresponding pilot project is underway in Malaysia with substantial participation by Enecolo, with the support of the SAEFL [43]. Although the PV EZA platform project was formally completed in 2003, its work is to continue based on a broader promotion platform for renewable energies in the context of international cooperation.

Alpha Real is representing Switzerland in TC 82 of IEC and is heading the working group to prepare and issue **proposals for international standards** [78] on 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. Certain aspects of these endeavours, including training, are also being treated in the EU Altener project **Quality in the Photovoltaic Sector** [77], which was completed successfully in autumn 2003.

The EU **PV-EC-NET** [40] project is a network combining the national PV coordination centres, in which 14 countries are participating (www.pv-ec.net). Over the report period, various international workshops were organized under the project. The different approaches adopted in the various European photovoltaics programmes were compared and analysed, and reports prepared on them. As a final step, a Roadmap is to be prepared presenting important future programmatic aspects both at the national and EU levels. The project should be regarded as an exploratory initiative aimed at European research as a whole. In addition to this, the new EU **PV-NAS-NET** [41] project is concerned with analysing the photovoltaics situation in Eastern European countries, whereby its work will proceed along similar lines to the PV-EC-NET project (www.pv-nas.net). These projects will provide an excellent overview of the various approaches and activities, and also on problems and opportunities for improvements.

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, CTI, the TOP NANO 21 programme, SAEFL, SDC and seco, and also with 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 and PV GAP was mentioned above. At project level, cooperation within the EU on new and existing projects continued in 2003. This involved 21 projects under the EU's *DG Research* and 3 projects under *DG Transport & Energy*. Further projects are in progress in the EU *IST* and *Altenet* programmes. 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.

Further contacts were maintained with the international organisations 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 projects

INTRODUCTION

P+D projects are an indispensable link between research and development and the implementation of the results in industrial processes, products and installations. P+D projects lie close to market applications. An important objective of these is to ensure continuing implementation of proposed developments. This requires not only building of installations with a pilot character, but also placing emphasis on the creation of suitable conditions for industrial implementation of the knowledge acquired. Special emphasis is therefore on fostering new processes and products that can be taken up by industry and introduced to the market. A further important aspect in connection with P+D projects is to maintain a comprehensive and directed information activity. P+D projects are an important instrument in promoting practical application: their exemplary nature must therefore be properly communicated.

Overall, the number of active photovoltaics P+D projects in 2003 showed a slight increase to just over 45. As usual, several projects were still under consideration at the beginning of 2004. However, the realisation of these is now in jeopardy owing to the precarious financial situation in the P+D sector. The P+D activities were divided into pilot installations, studies, tools, measurement campaigns and component development. There was an ongoing demand for testing new components in full-scale P+D installations, and this remained a clear priority in 2003. Here, **photovoltaics building integration** continued to be the principal theme.

SYNOPSIS OF RESULTS

A substantial number of projects in the photovoltaics P+D programme have proved extremely successful in recent years.

Some years ago, Sputnik Engineering, in cooperation with the then called Biel Engineering School, now part of the University of Applied Sciences of Berne, performed an exemplary programme of photovoltaics research and P+D projects in establishing the scientific foundations, developing prototypes and performing full-scale tests of power inverter technology. The SolarMax units (Fig. 12) resulting from this work have meanwhile successfully been launched on the European market. Annual production now tops 40 MWp capacity, securing about 50 jobs at Sputnik and its suppliers, both in Switzerland and abroad. This figure may be compared with the 1.7 MWp capacity produced per year for the Swiss PV market.

A further example selected from the list of successful projects is the SOLRIF roof integration frame [87] (Fig. 13), a photovoltaics P+D development realised in cooperation between the two companies Schweizer Metallbau and Enecolo. Following their introduction to the European market, a total of some 5 MWp of SOLRIF frames for roof integrated installations have been supplied.



Figure 12: Solarmax 2000 / 3000
(Photo: Sputnik Engineering)



Figure 13: Erni' solar house with SOLRIF roof integration (Photo: Enecolo)

The high quality of Swiss P+D photovoltaics projects is constantly being underscored by national and international awards. Examples of this are the application of SOLRIF to the photovoltaic roof of the Floreny multi-family house in Lausanne (Fig. 14, Swiss Solar Prize 2003), the Sunny Woods six-family house [49] (Fig. 15, European and Swiss Solar Prizes 2002), Midfield Dock at Zurich Airport [62] (Fig. 16) and Parking de l'Etoile in Geneva [86] (Fig. 17, both awarded the Swiss Solar Prize in 2002).

These examples serve to spotlight the creative flair behind Swiss projects and products, whose inventiveness often gives rise to emulation on the international scene. Repeatedly, Swiss innovation thus have set new technological standards.



Figure 14: Floreny SOLRIF roof integration in Lausanne
(Photo: NET)



Figure 15: Sunny Woods 16 KWp roof integration
(Photo: Beat Kämpfen Architectural Consultants)



Figure 16: Dock Midfield PV shading installation
(Photo: unique / Ralph Bensberg)



Figure 17: Parking de l'Etoile roof integration in Geneva
(Photo: Sunwatt Bio Energie)

At present, several PV P+D projects are concerned with the introduction and implementation of a range of thin film cell technologies. In addition to detailed measurement campaigns to determine the fundamental operating characteristics of these types of modules, their suitability for building integration is being studied in several projects. Previous experience demonstrates the suitability of several thin film cell products for direct integration in thermally insulated roofs and facades without back ventilation. Further development of these solutions offers extended opportunities for cost reduction in building integration schemes.

P+D PROJECTS

New P+D Projects

In 2003, 13 new projects were begun in the PV P+D programme. In concert with the national photovoltaics programme 2000-2003, the majority of projects concern photovoltaic installations in the built environment, whereby this year the percentage of flat roof applications has increased in comparison to other types. A new system for flat roofs was taken into operation in December 2003 in Trevano [50] (Fig. 18). This involved a combination of flexible plastic membranes with amorphous thin film modules. Two new hybrid stand-alone PV installation schemes progressed to the pilot stage (PV combined with fuel cells [57], and PV combined with a coupled heat and power unit (CHP) [89]). Owing to the rapid pace of development, it was urgent to bring the older Swiss PV regulations for photovoltaic installations up to date, to amend or replace them by integrating the current IEC regulations in the national installation standards NIN [73].

The projects begun in 2003 were as follows (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) [44]

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) [50], Fig. 18.
- ↓ 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) [88].
- ↓ 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: Muntwyler Energietechnik) [89].
- ↓ 16.3 kWp flat roof installation with thin film modules at ETH Zurich (optically unobtrusive flat roof integration with amorphous cells. Management: Zagsolar) [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].
- ↓ 12 kWp Solight pilot plant (pilot application of two different Solight variants on the flat roof of the VBZ/S railway station in Stettbach. Management: Energiebüro) [53].
- ↓ 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) [46], Fig. 19.
- ↓ 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) [57].



Figure 18: Construction of the CPT Solar Trevano
(Photo: LEEE-TISO)



Figure 19: Pfadiheim Weiermatt roof integration installation in Köniz (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) [66], Fig. 20.
- ↓ Wittigkofen measurement campaign (detailed measurements and evaluations with data visualization on the 80 kWp facade in Wittigkofen. Management: Ingenieurbüro Hostettler) [67], Fig. 21.



Figure 20: Stand-alone 3 kWp roof integration in Soyhières (Photo: NET)



Figure 21: 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) [73].
- ↓ 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) [74].

Current P+D projects

Among the current projects, the initial results of the PV ThinFilm test project in Zurich, particularly those related to photovoltaics building integration with thin film modules, are of interest. However, it is still too early for final conclusions to be drawn. Nevertheless, some of the modules appear to be suitable for direct PV building integration, either *with* thermal insulation or *without* back ventilation [68], Fig. 22.

The 3.9 kWp PV shading installation with CIS cells integrated in the Würth company building in Chur is an optically interesting variant. Measurements begun at the beginning of 2003 have demonstrated the expected energy yield of over 1100 kWh/kWp [58], Fig. 23.

The 70 kWp Palexpo flat roof installation is remarkable for its inconspicuous integration and the uniform appearance of its multicrystalline cells. As usual with modern installations, an excellent yield of around 1000 kWh/kWp was achieved up to now [55], Fig. 24.

The 5.5 kWp Freestyle® roof integration with amorphous thin film cells in Lutry near Lausanne well suits the building's modern architectural design. The installation, which is distributed over four different parts of the roof, supplies electricity to the grid via a Sunny Boy Multistring power inverter. To ensure a uniform appearance, the colour of the roof fittings was chosen to suit the modules [47], Fig. 25.

Two facade integrated installations were fitted in the lower and summit stations of the final section of the Piz Nair cable railway, giving measured performances of 9.7 and 13.5 kWp respectively. The dynamic play of light on the multicrystalline cells lends a special charm to these two buildings [59], Fig. 26.



Figure 22: PV ThinFilm test
(Photo: NET)



Figure 23: PV shading installation Würth, view of the inside, Chur (Photo: NET)



Figure 24: 70 kWp Palexpo flat roof installation in Geneva (Photo: NET)



Figure 25: Freestyle® roof integration in Lutry (Photo: Solstis)

Current projects comprise (in chronological order):

Component development

- ↓ Alpur photovoltaic roof installation (photovoltaics roof with thermal insulation, building integration. Management: ZAGSOLAR) [45]

Installations

- ↓ 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]
- ↓ 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) [58], Fig. 23.
- ↓ 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) [55], Fig. 24.

- ↓ 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) [47], Fig. 25.
- ↓ 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) [59], Fig. 26.
- ↓ Photovoltaic obelisk (pilot realisation of attractively designed information columns with integrated stand-alone PV installations for supplying the necessary electricity. Management: Enecolo) [60], Fig. 27.
- ↓ 25 kWp Solgreen Kraftwerk 1 green roof installation, Zurich (exploratory use of a newly developed support module for green roofs. Management: Enecolo) [56], Fig. 28.
- ↓ 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) [64].
- ↓ 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) [65].

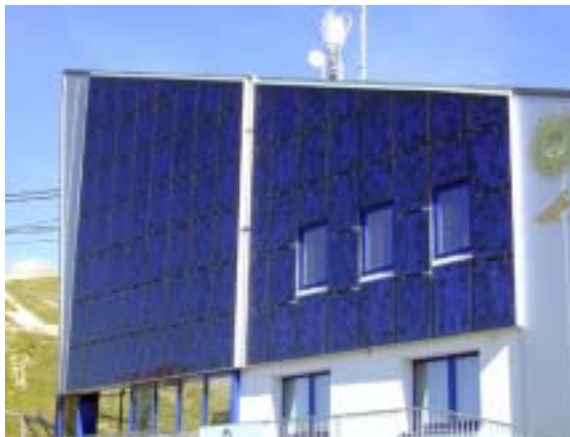


Figure 26: 9.7 kWp facade Piz Nair lower station
(Photo: NET)



Figure 27: Stand-alone photovoltaic Obelisk, Zurich
(Photo: Enecolo)

Measurement campaigns

- ↓ Migros PV ThinFilm test, Zurich (18 test installations with PV thin film modules in juxtaposition. Total capacity: 24.5 kWp. Management: Energiebüro) [68], Fig. 22.
- ↓ 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) [69].
- ↓ 47 kWp IBM installation (detailed measurement campaign on the properties of self-cleaning surface coatings of PV modules: Management: awtec, Zurich) [71], Fig. 29.
- ↓ Measurement campaign on the 100 kWp installation along the A13 (Management: TNC Consulting) [72].



Figure 28: Solgreen Kraftwerk 1 green roof installation
(Photo: NET)



Figure 29: 47 kWp IBM flat roof installation, Zurich
(Photo: NET)

Studies - tools - various projects

- ↓ Solar *Electri* City Guide – Swiss solar electricity guide for municipalities. (Management: NET) [75].
- ↓ Standards for PV systems. (Management: Alpha Real) [78].
- ↓ Swiss photovoltaic internet portal 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 2002 (Management: Energiebüro) [B].
- ↓ Solar electricity from the utilities (Management: Linder Kommunikation) [C].

Projects completed in 2003

The following P+D projects were completed in 2003 (in chronological order):

Component development

- ↓ Inexpensive monitoring of photovoltaic installations (development of a simple and inexpensive monitoring unit for solar installations with wireless data transmission. Management: NewLink Anderegg) [83], Fig. 30.

Installations

- ↓ 12.75 kWp PV roof integration Wettingen (harmonious PV roof integration in the historic village center of Wettingen, where the attempt was made to achieve an inexpensive solution using standard components. Management: Eigentümergeinschaft P.P. Stöckli / H.-D. Koeppel and Energiebüro) [48], Fig. 31.
- ↓ 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) [49], Fig. 15.

- ↓ 10 small-scale roof integrated PV systems (small-scale integrated PV installation (240 Wp), most of which were combined with a solar thermal installation. Management: Ernst Schweizer Metallbau) [79].
- ↓ 3 kWp PV Eurodach amorph (thermally insulated PV metal jointed roof with amorphous triple cells, building integration. Management: PAMAG Engineering) [80], Fig. 32.
- ↓ 10 kWp SolGreen installation integrated in a green roof (newly developed support structure for green roofs, flat-roof integration. Management: ars solaris hächler) [81], Fig. 33.
- ↓ 75 kWp PV noise barrier installation A1 Safenwil (combination of photovoltaics with a wooden noise barrier in modular construction using partly prefabricated elements. Management: Ekotech) [82], Fig. 34.
- ↓ 16.8 kWp photovoltaic installation St. Moritz with CIS modules (exploratory use of modules with CIS technology in an installation of this size, extensive measurement campaign. Management of installation part: Rätia Energie; management of measurement part: SUPSI, LEEE-TISO) [61], Fig. 35.
- ↓ 283 kWp photovoltaic installations at Dock Midfield, Zurich airport, including a 55 kWp PV demonstration plant (multifunctional photovoltaic building integration with shading facility, with particular requirements on the mechanical stability of modules. Management: ARGE Zayetta) [62], Fig. 16.
- ↓ Electrically driven passenger ship with PV supply (catamaran seating 150 persons with a stand-alone 20 kWp installation for supplying the drive motor. Management: Minder Energy Consulting) [63], Fig. 36.
- ↓ Héliotrope, 3x2 kWp PV installations in Le Locle (direct comparison of identical, but differently installed, systems (building integration, stand-alone, tracking. Management: EIAJ, Le Locle) [84].
- ↓ Photocampa: multifunctional PV shading installation (Parking de l'étoile, école de cirque, école de Lullier, Midfield Dock, Zurich airport, EU project. Management: Windwatt SA) [86], Fig.17.

Measurement campaigns

- ↓ Newtech, comparison of three 1 kWp installations (direct comparison of three installations with different thin film cell modules – a-Si tandem cells, a-Si triple cells, CIS cells. Management: HTI Burgdorf) [70], Fig. 37.



Figure 30: SMS Box Newlink
(Photo: Newlink)



Figure 31: 12.75 kWp roof integration in Wettingen
(Photo: NET)



Figure 32: 3 kWp PV Eurodach with amorphous cells
(Photo: NET)



Figure 33: 10 kWp Solgreen green roof installation
in Chur (Photo: NET)



Figure 34: 75 kWp noise barrier installation A1 Safenwil
(Photo: BFE)



Figure 35: 16.8 kWp installation with CIS cells in
St. Moritz (Photo: NET)



Figure 36: Mobicat solar catamaran
(Photo: NET)



Figure 37: 3x1 kWp Newtech test installations in
Burgdorf (Photo: NET)

Studies - tools - various projects

- ↓ Integration of combined PV and thermal collectors in building systems (Management: S. Kropf, ETH Zurich) [85].
- ↓ REMAC Renewable Energy Market Accelerator (measures to accelerate the market for renewable electricity. Management of Swiss contribution: NET) [76].
- ↓ Quality is the key of the PV market – accreditation / certification (preparation of quality assurance programmes for photovoltaics. EU Altener project. Management: Alpha Real) [77]. Also see work on standards [78].

6. Assessment of 2003 and perspectives for 2004

The international photovoltaics market is booming thanks to extensive promotion programmes and incentives for photovoltaic grid supply in certain countries, with growth rates of between 30 and 40%. In contrast, the Swiss photovoltaics market remained subdued in 2003, although the figures for the previous year could be upheld thanks to the solar stock exchanges. In recent years, very different situations regarding photovoltaics have arisen in the regions. Though this situation must be regretted, it is no more than a natural consequence of the autonomy of the cantons and municipalities. The IEA PVPS market data for individual countries show that whilst Switzerland is falling behind developments both relatively and in comparison to the largest of today's markets – particularly in Germany and Japan – her position remains enviable in comparison to many other countries. Swiss photovoltaics was well represented at the 3rd World Photovoltaics Conference in Osaka in May with several projects, the Swiss delegation bringing home two awards [114].

The discussions concerning the future of the SwissEnergy action programme remained a major theme during the report period, and led to considerable uncertainty on the part of all concerned. The cuts now decided on will first hit the P+D projects, and will have serious effects on the future direction and possibilities within the photovoltaics programme. This development is very regrettable, since it will weaken the vital links between research and development and industrial products and processes, as well as those to the market. It would be quite inconsistent to jeopardize the implementation activities in the photovoltaics programme at a time when these are beginning to expand following exhaustive efforts in the past.

P+D projects are an indispensable link between research and development and the implementation of their results in industrial processes, products and installations. They lie in close proximity to practical application and to the market. An important objective of P+D projects is to ensure continuing implementation of the proposed systems. This requires not only that installations with a pilot character be built, but also that special emphasis be placed on creating the necessary conditions for industrial implementation of the experience gained. Thus the objective must be to foster new processes and products, which then may be taken up by industry and put on the market.

Thanks to broadly-based promotion of the photovoltaics programme, the number of projects and the level of public funding could be maintained despite the difficult financial situation. EU projects in conjunction with the financial support provided by the Federal Office for Education and Science (OFES), and the support of the Commission for Technology and Innovation (CTI), have contributed to this. The excellent networking of the programme and the interaction between the players, both nationally and internationally, have provided the essential basis, and this aspect will continue to receive full attention. It will be critical to find an alternative source of finance to substitute the previous funding for P+D projects.

Like importance is attached to the continuing exchange of information. The photovoltaics website in German www.photovoltai.ch has been in full service since autumn 2003. The English and French versions are in preparation. The most important national event in 2004 is the 5th National Photovoltaics Meeting at the ETH Zurich (25/26 March 2004). The second day is entirely devoted to the theme of photovoltaics building integration. In addition, the 19th European Photovoltaics Conference is taking place in Paris (7-11 June 2004) and the 19th Symposium for Photovoltaic Solar Energy in Staffeldstein (10-12 March 2004).

7. List of R+D projects

(AR) Annual Report 2003 available

(FR) Final Report available

ENET: ENET order number of the report

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11. Abbreviations (incl. internet links)

General

PV EZA Swiss Platform Photovoltaics – development cooperation <http://www.photovoltaiic.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/d/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 |
| EWZ | Elektrizitätswerk der Stadt Zürich | http://www.ewz.ch |
| HTI | Berne University of Applied Sciences / School of Engineering and Information Technology | http://www.hti.bfh.ch |
| HTW | University of Applied Sciences Chur | http://www.fh-htwchur.ch/ |
| ICMB | Institute of Molecular and Biological Chemistry | http://icmb.epfl.ch/ |
| IMT | Institut de Microtechnique Université Neuchâtel | http://www-imt.unine.ch |
| IQE | Institute of Quantum Electronics ETHZ | http://www.iqe.ethz.ch |
| LEEE - TISO | Laboratory of Energy, Ecology and Economy - Ticino | http://www.lee.e.supsi.ch |
| LESO | Laboratoire d'Energie Solaire EPFL | http://lesomail.epfl.ch/ |
| NIN | Low Voltage Installation Standard | http://www.electrosuisse.ch/ |
| OFES | Swiss Federal Office for Education and Science | http://www.bbw.admin.ch/ |
| OPET | Swiss Federal Office for Professional Education and Technology | http://www.bbt.admin.ch |
| PSI | Paul Scherrer Institut | http://www.psi.ch |
| SAEFL | The Swiss Agency for the Environment, Forest and Landscape | http://www.umwelt-schweiz.ch/buwal/de/ |
| SDC | Swiss Agency for Development and cooperation | 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 |
| SFOE | Swiss Federal Office of Energy | http://www.energie-schweiz.ch |
| SUPSI | Scuola universitaria professionale della Svizzera Italiana | http://www.lee.e.supsi.ch |

International organisations

| | | |
|----------|--|---|
| EU (RTD) | European Union (RTD-Programme) Community Research & Development Information Service | http://www.cordis.lu |
| EESD | Energy, Environment and Sustainable Development | http://www.cordis.lu/eesd/ |
| ESTI | European Solar Test Installation | http://ies.jrc.cec.eu.int/ |
| IST | Information society technologies | http://www.cordis.lu/ist/ |
| 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 |
| PV GAP | PV Global Approval Programme | http://www.pvgap.org |
| UNDP | United Nations Development Programme | http://www.undp.org |

Privat institutions and companies

| | | |
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| NOK | Nordostschweizerische Kraftwerke | http://www.nok.ch |
| | 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 |
| GWF | Swiss Science Agency | http://www.gwf-gsr.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 2003

Thin film silicon solar modules: Contributions to low cost industrial production

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| Project- / Contract Number | 100045 / 150046 |
| Duration of the Project (from – to) | 1.1.2003 - 30.6.2004 |

ABSTRACT

During the reporting year (2003), the photovoltaics research group at IMT Neuchâtel was able to mark a significant step in the transfer of its research results to Industry. A licence and a collaboration agreement with the internationally active firm UNAXIS AG (manufacturer of production equipment for active-matrix liquid-crystal displays) was concluded in March 2003. UNAXIS is now committed in a joint R&D effort to adapt its production equipment to the solar cell technology initially developed by IMT.

On the other hand, the PV research group at IMT had in 2003 to negotiate a difficult transition period on the level of the departure of four key staff members, several projects ending at the same time and of an unexpected and undesired delay in the appointment of the new head of the group (successor of Prof. A. Shah). Nevertheless, significant research results and a better understanding of thin-film silicon devices could be achieved by IMT, during 2003:

On the path to cut down production cost of thin-film silicon solar modules, a bottleneck is the production time for microcrystalline silicon ($\mu\text{c-Si:H}$) absorber layers. Since these layers originally had a thickness of at least $2\mu\text{m}$, IMT attempts to increase deposition rate whilst maintaining at the same time solar-grade material quality. Rates up to 2.5 nm/sec for films on glass and first promising $\mu\text{c-Si:H}$ solar cells in the p-i-n configuration could be achieved by using higher deposition pressures.

A second approach to low-cost solar cells is an optimisation of optical absorption within the cell absorber. In this field, randomly growth-textured substrates were intensively studied and compared with periodic diffraction gratings. Within this study, IMT fabricated $\mu\text{c-Si:H}$ solar cells in the n-i-p configuration on flexible PET substrates with a conversion efficiency of $\xi=5.2\%$ which is, to the best of our knowledge, a world record. In the field of Transparent Conductive Oxides (TCO) for cell contacts, the development of Zinc Oxide could be pursued. Due to large pyramidal ZnO grains, an optimal light-scatterer for thin-film solar cells has been explored and found.

The electrical and structural characterisation of thin-film solar cells and films (e.g. by Raman spectroscopy) revealed a correlation between interfaces and the V_{OC} of the device. This work has been honoured by the «young scientist award» given to Ms. Corinne Droz at the World PV Conference held in Osaka (Japan).

Annual Report 2003

DOIT - Development of an Optimized Integrated Thin-film silicon solar module

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| E-mail, Homepage | Nicolas.wyrsh@unine.ch , http://www-micromorph.unine.ch |
| Project- / Contract Number | BBW 00.0337 / ENK6-2000-00321 |
| Duration of the Project (from – to) | 1.1.2001 – 31.12.2003 |

ABSTRACT

This European project aims at the development of an innovative silicon thin film solar module, exhibiting a stabilised active area efficiency of 11% on a substrate size of 30x30 cm². The device consists of an amorphous silicon/microcrystalline silicon tandem solar cell (so-called micromorph cell) prepared on a low cost transparent conductive oxide (TCO) coated glass substrate. In view of industrial production, a deposition rate of at least 4 Å/s is to be achieved for the intrinsic layer of the microcrystalline silicon (μc-Si:H) bottom cell. Besides the scale-up of state-of-the-art small area micromorph cells prepared by Very High Frequency Glow Discharge (which is the main task of IMT), an alternative approach will be followed using lower excitation frequencies (by the Forschungszentrum Jülich); the latter approach is more compatible with current a-Si:H production technology. Implementation of advanced plasma control tools should ensure a successful scale-up here.

The development of this innovative solar module also includes the module fabrication technology with monolithic integration of the electrical series connection, and the study of efficient light trapping schemes. For the latter objective, this project is focussed on the choice and use of the most appropriate TCO layer available (either on the market or from other running European projects), rather than on the development of new TCO layers; it relies, furthermore on extensive optical characterisation techniques and modelisation in order to optimise light trapping within the solar cells.

During the first two years of this project, IMT has successfully completed the construction of a large-area (30x30 cm²) two-chamber reactor for the deposition of a-Si:H and μc-Si:H layers and cells. Using this deposition system, μc-Si:H intrinsic layers were deposited with acceptable uniformity at rates up to 10 Å/s; uniformity better than 10% (30x30 cm²) was achieved at a deposition rate of 4.5 Å/s. First μc-Si:H cells with 3% efficiency were also fabricated.

During the last year of this project, several modifications in the equipment and in the cleaning procedures had to be introduced in order to decrease the high oxygen contamination of the cell and to enable higher cell efficiencies. With these unexpected problems, the milestones of 5% (due at the end of 2002) was only achieved during Summer 2003. A further improvement (above 6%) is expected for the end of 2003, however, without meeting the final milestone of the project. Delays introduced by several deposition system failures in 2002 and the mentioned oxygen contamination problems (due to both the system configuration and to the chosen cleaning process) in 2002/03 could thus not be fully compensated for.

Annual Report 2003

Large area and high-throughput coating system (PECVD) for silicon thin-film solar cells

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| Project- / Contract Number | KTI 5994.2 |
| Duration of the Project (from – to) | August 2002 - August 2003 |

ABSTRACT

The main goal of the present project was to obtain "stable" large area p-i-n solar cells at a moderate deposition rate of $3\text{\AA}/\text{s}$. Such deposition rates are already industrially acceptable if the cell specification can be maintained after light soaking. In the frame of the project it has been demonstrated that the Unaxis KAI plasma box reactor allows a suitable single-chamber process for the production of large area solar cells and that the obtained performances of the solar cells are in accordance with industrial cell specifications. In particular, the problem of the reduction of the boron contamination in the reactor after the p-layer deposition, a problem specific to single chamber processing, has been successfully solved and a patent has been filed.

Annual Report 2003

Aufrauen von Polymersubstraten

Gezieltes Aufrauen von Plastikfolien für ein effizientes Light-Trapping in amorphen Solarzellen

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| Project- / Contract Number | BFE 42919 / 82868 |
| Duration of the Project (from – to) | 1.10.2001 - 30.4.2003 |

ABSTRACT

The objective of the project was the introduction of light-trapping for a-Si:H solar cells deposited on polymer foils by applying plasma roughening of the substrate.

The preliminary experiments showed that Reactive Ion etching (RIE) using SF₆ / O₂ mixtures can result in surface roughnesses on the order of 0.1 to 1 μ m. Such surfaces were analysed and compared by using AFM, scanning electron microscopy and angular resolved reflection. Here, the angular resolved reflection proved to be particularly useful as a clear quantitative interpretation is possible on the basis of the critical angle of escape of 28°.

Regarding etching parameters to obtain usefull roughnesses, the electrode configuration was found to play a predominant role. The best results were obtained by applying a set of powered linear electrode bars in front of the substrate foil.

To apply such textured etched substrates to actual solar cell fabrication, a continuous etching system was realized comprising a linear etching electrode and a roll-to-roll foil transport mechanism capable of treating 300 mm wide foils.

In solar cell fabrication on textured etched films, at first the yield was very low. This was related to a coverage of the etched film with a layer of reaction products. These structures could be eliminated by a cleaning step, leading to an again reasonably high yield.

Based on this procedure, n-i-p type solar cells could be successfully fabricated on textured etched polyimide substrates. The increase of the photocurrent and the efficiency over flat substrates was of +10%, with the best solar cell reaching an initial conversion efficiency 6.9 %.

Annual Report 2003

Generation of random nano-patterns in polymer surfaces due to replication of nano-crystal grain-boundaries

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| Project- / Contract Number | KTI 6059.1 TNS |
| Duration of the Project (from – to) | 01.10.2002 – 31.03.2004 |

ABSTRACT

Aluminium diffuses already at 200°C into silicon and creates a locally enhanced Al-concentration in the silicon lattice. The application of selective etching either for silicon or for Aluminium reveals these “centers” that have extensions at nanometric dimension. In the case of nano-crystalline silicon, grains and grain-boundaries control this effect. Within the framework of the project, diffusion and subsequent etching create a natural mask that allows roughening of a polymer substrate for thin-film silicon solar cells with the objective to increase the efficiency due to light-trapping.

In the first project phase, the following results were obtained:

Two sample configurations were used to produce a nanopatterned polyimide substrate. The original configuration: polyimide/Al/Si was proved to be inefficient due to native alumina layer formed at the Al surface prohibiting Al diffusion into Si. The second (inverted) configuration: polyimide/a-Si/Al showed an interesting diffusion behaviour. The heat treatment in dry N₂ at 200-250°C caused a Si-Al interdiffusion. This process is called Aluminium-induced Crystallisation (AiC). As a result of AiC, Si diffused through Al layer and formed the islands at the surface. The subsequent etching procedures were performed in order to remove selectively Si by RIE and Al by wet etching. These etching steps produced different interesting nano-patterning structures of a sub-micron size.

Annual Report 2003

Étude et amélioration de la fiabilité des cellules solaires sur substrats polymères

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| Project- / Contract Number | 100296 / 150368 |
| Duration of the Project (from – to) | 1.7.2003 - 31.3.2004 |

ABSTRACT

VHF-Technologies is a startup company industrializing amorphous silicon solar cells on plastic substrate. The original technology was developed at the University of Neuchâtel, from which VHF-Technologies has licensed the VHF high deposition rate process. VHF-Technologies is entering now the commercialization phase of its flexible solar cells on the markets of stand-alone power supply and of flexible solar chargers.

In order to be able to launch the product on the outdoor application market, the long-term reliability of the product has to be assured. Preliminary accelerated lifetime tests (thermal cycling $-40\dots85^{\circ}\text{C}$ under high humidity) showed delamination of the thin films from the polyimide substrate along with a loss in output power. In order to solve this crucial issue, an R&D program was defined along the following lines of investigation:

- € Improvement of the adhesion of the metallic back contact layer on the polyimide substrate
- € Control and limitation of the absorption of water in the substrate film during the coating process, and also during the lifetime of the solar cell
- € Reduction of the stress in the solar module structure in order to reduce the tendency of delamination.

After the first part of this program, the following results were obtained:

- € Extension of the PVD coating system for fabrication of sputtered back contact layers completed
- € Lift-off structuring of the PVD metallic back-contacts leading to a solar module production yield of over 90%
- € Application of combined infrared substrate degassing and anodic plasma treatment leading to power losses of less than 5% after 10 thermal cycles, and over 90% of the tested modules showing no peeling at all

Annual Report 2003

RE-Si-CLE: Recycling of Silicon Rejects from PV Production Cycle

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| Project- / Contract Number | N° OFES: 01.0311 / N° UE: ENK5-CT2001-00567 |
| Duration of the Project (from – to) | 01.01.02– 31.12.04 |

ABSTRACT

The general objective of the RE-Si-CLE project is the recycling of silicon from silicon containing waste that is produced by the multi-crystalline silicon based PV industry. The development activities of the project focus on recovering silicon from used-up wafer sawing slurries (mixtures of oil or glycol with Si particles, SiC powder and Fe/Fe_xO_y particles). The main motivation behind Si reclaiming is the general Si feedstock shortage. At present, the accumulated silicon waste in form of fine silicon powders within slurries amounts to 34 % of the silicon that enters the multi-c silicon PV production chain. This quantity corresponds to 5.1 tons of silicon per MWp module power produced. This situation will become even more acute as production trend nowadays is toward thinner wafers.

As of today, the following specific points were achieved:

- Granulometric and chemical analysis of different types of fresh and exhausted slurries
- Application and adaptation of existing equipment for the recycling of SiC and the liquid in order to produce a Si rich paste-like residue mix called "sludge". Demonstration of 90% kerf (Si saw dust + metal residues) extraction efficiency from exhausted PEG-based slurry.
- Chemical and mechanical approach to remove Fe and other metals from the sludge, general feasibility of the processes, production of 2 x 10 kg dried Si powder with strongly reduced Fe content
- Heat treatment to remove the residual liquid from the sludge and to arrive at solid silicon pieces for the final purification stages
- Definition of most effective purification conditions (highest performance and minimal Si losses), in terms of processing windows by chemical modelling of the purification process
- Calculation of acceptable impurity concentrations in the silicon at different stages of the recycling and purification treatment in order to arrive at high efficient solar cells.

Annual Report 2003

Production of large area CIS modules (PROCIS)

| | |
|-------------------------------------|--|
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| Project- / Contract Number | BBW 00.0402 / ENK5-2000-00331 |
| Duration of the Project (from – to) | 01.01.2001 – 31.12.2003 |

ABSTRACT

High efficiency CIGS solar cells have been developed with chemical bath deposited (CBD) buffer layers. However, for an in-line production of modules vacuum deposition processes (PVD) are preferred for compatibility reasons and high throughput. Moreover, high band gap alternative buffer layers are needed to reduce the optical absorption losses in low spectral wavelength range.

We have developed CIGS solar cells CBD- and PVD-CdS and compared the photovoltaic performance. Solar cells prepared with ~80 nm thick HVE-CdS yield cells of 10-12 % (without any surface treatment of the CIGS layers), while reference cells with CBD-CdS have 14-15 % efficiency.

Wide band gap ZnS and ZnSe buffer layers were applied as an alternative to CdS in CIGS solar cells. Layers of different thickness were grown by e-beam and thermal evaporation at different substrate temperatures. A post-deposition annealing was applied in order to control the diffusion of Zn into the CIGS. Upon light soaking, increase in Voc and FF are measured. Post deposition annealing in air and a subsequent light-soaking showed to be crucial for high efficiency, as it increased from 5.8% to 9.1 % for the cells with ZnS buffer layer. Solar cells with Zn-chalcogen buffer layers exhibit high spectral response in low wavelength range (350-500 nm) but the overall collection efficiency is low.

Production of CIGS modules with high throughput on soda-lime glass substrates requires simple and controllable CIGS deposition process, preferably at low temperatures (400-450 °C). We have compared the structural and chemical properties of CIGS layers grown with different recipes at ETHZ and investigated the effect of Na diffusion from the glass substrates. We conclude that though Na in CIGS is desired for efficiency improvement, it's presence during the growth inhibits the CIS or CIGS phase formation, it inhibits the In-Ga inter-diffusion, but leads to smoother morphology of CIGS. Preliminary studies of the kinetics of MoSe₂ formation have been performed.

Annual Report 2003

New buffer layers for efficient chalcopyrite solar cells (NEBULES)

| | |
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| Project- / Contract Number | BBW 02.0074 / 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)Se₂ (CIGS) solar cells developed with different type of buffer layers.

CIGS based thin-film solar cells with high efficiencies of 15-19% have been developed using CdS buffer layers grown by a chemical bath deposition (CBD) method. For industrial production, an in-line vacuum deposition, e.g. physical vapor deposition (PVD), of the CdS buffer layer is aspired. However, the highest efficiencies achieved with PVD-CdS buffer layers hardly exceed 13%. To understand the underlying reasons, structural and chemical properties of CBD- and PVD-CdS buffer layers and their interfaces with CIGS were investigated by means of bright-field transmission electron microscopy (BF-TEM), high-resolution TEM (HR-TEM), energy-dispersive X-ray spectroscopy (EDX) and scanning electron microscopy (SEM). Contrary to the general speculation, PVD-CdS layers show a uniform conformal coverage of the CIGS surface, similar to the CBD-CdS coverage. Both BF-TEM and SEM images show significantly larger grain sizes for the PVD-CdS layer compared to the CBD-CdS layer. 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. This suggests that the CIGS surface oxide layer is *in-situ* etched away in CBD solution prior to the CdS deposition, while it has a detrimental effect on the photovoltaic properties of the cells with PVD-CdS.

A trend in CIGS solar cells is to develop solar cells with alternative buffer layers that can substitute CdS layer. Recently, ZSW, Stuttgart and ENSCP collaboration reported 16.4% efficiency CIGS cells with an In₂S₃ buffer layer grown by atomic layer deposition method. We have investigated the structural properties of In₂S₃ buffer layers and CIGS-In₂S₃ interfaces. The buffer layers show uniform conformal coverage and the typical grain size is ~50 nm. Crystallographic orientation relationship and inter-diffusion across the interface depends on buffer layer deposition temperature. Preliminary measurements indicate diffusion of Cu from CIGS into In₂S₃ buffer could be detrimental to the structural and electronic properties of the heterojunction.

Annual Report 2003

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

| | |
|-------------------------------------|--|
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| Project- / Contract Number | BBW 01.0108 / 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)Se₂ (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 Na in CIGS for high efficiency solar cells.

CIGS solar cells on spin coated polyimide and subsequent lift-off removal of the glass substrate were earlier developed on 3 x 3 cm² substrates. The efforts are now being made to scale-up the area, solve the problems of defect formations (bubbles, micro-cracks) and reduce the time needed for lift-off removal of the solar cell stack from the carrier (substrate). Spin-coating polyimide has been scaled up for deposition up to 10 x 10 cm² substrates. Various buffer layers were investigated for a faster removal (lift-off) process.

A novel process was developed for a controlled incorporation of Na in CIGS to improve the cell efficiency. A patent application has been filed (sponsored by Würth Solar GmbH). CIGS layers were grown by a co-evaporation method on soda-lime glass with and without Al₂O₃ barrier layer for Na diffusion. In case of Na free samples, Na was diffused into CIGS by a post deposition treatment method suitable for in-line manufacturing. This approach is compatible with existing manufacturing processes. This process led to a strongly improved device performance compared with Na-free cells. Passivation of CIGS grain boundaries is the dominating cause for Na-induced device improvements.

Solar cell efficiencies of 13.3% and 14.4% were achieved at substrate temperatures as low as 400°C and 450°C, respectively. These efficiencies are amongst the highest achieved with low deposition temperature processes.

Annual Report 2003

Nanomaterials for high efficiency and low cost Cu(In,Ga)Se₂ thin film solar cells

| | |
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| Project- / Contract Number | 5491.3 / - |
| Duration of the Project (from – to) | 1.12.2001 – 30.11.2003 |

ABSTRACT

Precursor pastes for CuInSe₂ (CIS) and Cu(In,Ga)Se₂ (CIGS) were deposited on molybdenum coated glass substrates by simple and low cost deposition methods. A subsequent selenization using non-toxic roots is performed to convert the precursor layers into CIS and CIGS layers. The chemical conversion is monitored by X-ray diffraction (XRD). The XRD results indicate the formation of CIS or CIGS respectively where impurity phase formation is below the detection limit of XRD. Scanning electron microscopy (SEM) and Energy dispersive X-ray spectroscopy (EDX) show homogenous films in composition, thickness and morphology, comparable to vacuum evaporated CIGS films. For completely processed solar cells with a Glass/Mo/CIGS/CdS/ZnO/ZnO:Al layer stack the photovoltaic properties are investigated by current-voltage measurements. Conversion efficiencies of 6.7% were obtained with simulated AM 1,5 standard illumination.

Annual Report 2003

Dye-sensitised Nanocrystalline Solar Cells

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| Project- / Contract Number | EPFL ; EPFL-V |
| Duration of the Project (from – to) | January – December 2003. |

ABSTRACT

Sensitised photoelectrochemical devices are a unique technical and economical alternative to the conventional solid-state junction photovoltaic devices for solar energy applications. The standard photovoltaic devices developed and applied over recent decades 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.

Annual Report 2003

Highly Efficient Nanocrystalline Solar Cells for Indoor Applications

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| Project- / Contract Number | 5815.1 / 5480.3 |
| Duration of the Project (from – to) | 36 months ; 2001 - 2004 |

ABSTRACT

The industrial partner, Greatcell Solar SA (GSA) has a specific product concept – dye-sensitised electrochemical photovoltaic cells for indoor use. The goals of this project are 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 indoors and therefore under reduced light levels. 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 critical to the development of the start-up company Greatcell Solar, as it provides key information and technology for its intended product.

Annual Report 2003

Flexible dye solar cells

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| Project- / Contract Number | TopNano 21 - KTI N580 2.3 / 4994.1 |
| Duration of the Project (from – to) | |

ABSTRACT

The dye-sensitised solar cell (DSC) has originated in this laboratory in Ecole Polytechnique Fédérale de Lausanne, and has been a key research topic in the Laboratory for Photonics and Interfaces. In the standard 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. 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 2003

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 present 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.

Annual Report 2003

Photochemische, Photoelektrochemische und Photovoltaische Umwandlung und Speicherung von Sonnenenergie

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| Project- / Contract Number | 76645 / 36846 |
| Duration of the Project (from – to) | January 2003 – December 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 O₂ 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. Water splitting capability tests were also carried out, where the AgCl photoanode was combined with hydrogen-producing semiconductors, such as a platinized silicon solar cell and platinized p-GaInP₂. AgCl layers were employed in the anodic part and the H₂ evolving semiconductors in the cathodic part of a photoelectrochemical cell for light-assisted water splitting. To increase the absorptivity of the AgCl photoanodes, the addition of sensitizing agents, chemical species that have a high absorptivity in the visible light spectrum, was tested. Improvement of sensitivity, and consequently in O₂ production, has been observed with Br⁻-sensitized AgCl photoanodes. Silver chloride electrodes were also sensitized with Au colloids. A considerably increased O₂ production of AgCl layers sensitized with Au colloids was observed under the same photoelectrochemical reaction conditions.

Host-guest composites with photonic antenna properties have been prepared. The materials consist of cylindrical zeolite L crystals, the channels of which are filled with chains of dye molecules. Light shining on a crystal is first absorbed and the energy is then transported by the dye molecules inside the tubes to the desired part. The synthesis principle we are using is based on the fact that molecules can diffuse into the channels of the zeolite. The general approach to connect the antenna function to its surroundings is to add "stopcock" molecules that generally contain a head, a spacer and a label. They can either trap excitation energy on the external surface or inject excitation energy into the dye-loaded crystal. The stopcock molecules act as a bridge between the dye molecules inside the channels and the outside world. We have now been able to demonstrate that electronic excitation energy can be transferred from the antenna via the stopcock to a semiconductor and vice versa. This marks a breakthrough in this research.

Annual Report 2003

Photoactive Composite Module

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| Project- / Contract Number | KTI 5581.1 FHS |
| Duration of the Project (from – to) | 1.4.02 – 31.12.03 |

ABSTRACT

The combination of an Alucobond facade element of Alcan Composites with flexible solar cells of VHF-Technologies is a completely novel possibility of integrating solar cells on facade elements. Both, Alucobond facade panels and VHF-Technologies' solar cells are produced in a roll-to-roll fabrication process, therefore a simultaneous and direct lamination of solar cells (off the roll) at the moment when the Alucobond is manufactured is feasible. Such a continuous roll-to-roll fabrication method is expected to be particularly cost competitive.

The goal of this project was to demonstrate the feasibility of this new photovoltaic facade element by the fabrication and testing of prototype modules. Simultaneously, the economical viability of the concept was to be assessed. The following results were obtained:

- € a process for fabrication of large area modules with a high yield was established at VHF-Technologies, yielding a stable aperture area efficiency of 3%
- € a large area module of 2000mm x 1000mm was fabricated on an Alucobond sheet, delivering 34 Watt_{peak}
- € a set of 5 laminates of 7 Watt of 1200mm x 300mm were connected to the grid and monitored over 8 months
- € with an improved technology, a stable efficiency of 4% was demonstrated after 6000 h of light-soaking
- € lifetime testing of up to 270 cycles of –40°..85°C at high humidity showed excellent stability of ETFE/EVA laminates on aluminum sheets and on Alucobond-sheets.
- € the electrical performance under temperature cycling was found to decrease due to an adhesion problem of the solar cell on its polymer substrate; a parallel SFOE-project was launched to resolve this problem
- € the economical analysis showed that the raw added materials cost for realizing a photoactive aluminium based building element are of CHF 31.00/m², or of CHF 0.62/W_{peak} assuming an efficiency of 5%.

Annual Report 2003

Photovoltaic Modules with Antireflective Glass

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| Project- / Contract Number | 100297 / 150369 |
| Duration of the Project (from – to) | 01.08.2003 - 01.11.2004 |

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 and yield analyses.

Annual Report 2003

HIPERB High Performance photovoltaics in buildings

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| Project- / Contract Number | EC: NNE5-1999-0233 (ERK6-1999-00009; BBW 99.0039) |
| Duration of the Project (from – to) | (1. April 2000); 1. Oktober 2001 to 31. September 2003 (CH 31.12.2003) |

ABSTRACT

The aim of the project is to develop high performance, high quality and stable thin-film PV modules for the integration into buildings (façades as well as roofs) forming a fully integrated part of the outer skin of the building. The work includes modules for the façade and modules suited for the replacement of roofing tiles and slates in an advanced manner resulting in performance and cost improvements as compared to the existing technologies and designs. All the aspects from cell and module technology to assembling and electrical interconnection and life-time testing are included. An important goal is to increase the public acceptance of PV in buildings by covering aesthetical aspects, architectural ideas and demands of protection of historic buildings. Security aspects and building regulations are also being considered.

Cost reduction is aimed at mainly by standardisation of products and parts, process optimisation and by giving the modules the potential to adopt multiple functions in the building (replacement of expensive decorative elements of façades and customary roof parts). The range of module sizes extends from small sized roof tile size to standard production module size (e.g. 1200mm x 600mm) and larger sizes which will be realised by assembling of submodules. Technologies used in structural glazing are being adapted for framing and fastening elements of the façade modules. Long-term stability will be analysed by procedures according to international standards.

The consortium combines manufacturers and developers of PV cells and modules with glass-manufacturers, producers of manufacturing equipment, partners providing materials and processes for module encapsulation (lamination with glass and/or polymers and cast resins) and an authority in the field of testing and module evaluation.

Annual Report 2003

AFRODITE Advanced Façade and Roof Elements Key to Large Scale Building Integration of Photovoltaic Energy

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| Duration of the Project (from – to) | (1. April 2001); 1. Oktober 2001 to 1. April 2004 |

ABSTRACT

The objective of this work is 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 are 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.

Annual Report 2003

ADVANTAGE Advances next generation rear contact module technology for building

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| Duration of the Project (from – to) | 2000 - 2003 |

ABSTRACT

The development period of the EU-project ADVANTAGE which lasted 30 months was concluded in September 2003. The development of rear-contact cells could not be finalised during this period. As a consequence the final glass modules with rear-contact cells could not yet be fabricated. Depending on the contacts of the solar cells, the pattern of the strip conductors on the glass is defined. The development of this pattern and the contacts of the whole assembly could successfully be terminated. Positive results could be obtained at different interfaces beyond the solar cell area; they enable the manufacturing of glass modules with conventional solar cells. Tests and samples indicate that such glass modules could be well adapted to building integrated photovoltaics. The requirements for such glass modules are however – depending on the applications and test rules – very demanding. Energy conversion surface, light transparency and the thermal conductivity are parameters which require particular attention for glass modules. Based on the different samples prepared, economically interesting manufacturing processes could be successfully investigated. Due to the new development and patented string conductors on glass, the lamination of solar cells is not needed. Therefore, recycling of glass modules becomes very easy and environmentally sound.

Annual Report 2003

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 2003, DEMOSITE continued to promote and stimulate the development of Building Integrated Photovoltaic:

- € Several group visits were organised on the site location in Lausanne, detailed explanations given during the tour. The visits also include a tour of several PV pilot installations on the EPFL site.
- € 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

DEMOSITE 1, the part of the exhibition located on the parking lot has seen the theft of 8 modules on the SOLFACE pavilion. As these modules are at ground level and easily reachable, they will be replaced by mock-ups.

Routine maintenance has been conducted, in particular replacing back panels blown away on the Kawneer pavilion

Possible uses for Demosite within the upcoming Task 10 are investigated

Annual Report 2003

Qualità e resa energetica di moduli ed impianti PV TISO - periodo VI: 2000-2003

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| Project- / Contract Number | 36508 / 76324 |
| Duration of the Project (from – to) | 1 January 2000 - 30 June 2003 |

ABSTRACT

During 2003, measurements on modules of cycles 9 at real operating conditions have been carried out. The initial power degradation was limited and after 9 months it was equal to about -3.2% (for c-Si modules), confirming data of previous cycles. The maximum power degradation was equal to -5.5%. After 8 years of functioning in real operating condition and with the modules of cycles 9 working at the limit of their power ranges, the electronics components of the maximum power point tracking showed relevant signs of degradation.

The «matrix method» has been further developed. In particular, the power matrix extrapolation from measured data has been improved introducing the Sandia National Laboratories method (US). During 2003 comparisons between different power matrix methods have been carried out with the ESTI laboratory (JRC).

The annual audit for the ISO 17025 accreditation of c-Si modules performance measurements @STC has been successfully passed. In particular, the uncertainty measurements has been improved after calibration of the reference cell performed by PTB (D). For third-parties measurements on c-Si modules an error of $\pm 2\%$ is given on measured power, without mismatch correction.

During 2003, about 1500 I-V measurements have been performed.

The I-V measurements service has been considerably increased, passing from 120 measurements in 2002 to 348 in 2003. This increase was also due to the Cantonal decree on the subvention for the realization of grid-connected PV plants.

The "international PV module measurement intercomparison" (Round Robin test) concerns the measurements of six pairs of different types of PV modules. In November 2003 the modules have been measured by the LEEE-TISO. This intercomparison, which will last till 2005, involves 10 laboratories of different Continents (USA, Germany, Italy, China, Japan and Switzerland).

The detailed analysis of the 10kWp TISO plant has been carried out. Complete results regarding the European SOLAREC project "Mean Time Before Failure" will be presented in the final report now in preparation.

Annual Report 2003

Mean Time Before Failure of Photovoltaic modules (MTBFPM)

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|-------------------------------------|--|
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| Project- / Contract Number | BBW 99.0579 |
| Duration of the Project (from – to) | 17.04.2000 – 16.04.2003 |

ABSTRACT

The Mean Time Before Failure (MTBF) project – a 3-year collaborative research program between the LEEE-TISO and the ESTI laboratory (JRC, IES, RE Unit, Ispra) - planned within the Project SOLAREC (5th European Framework Program), finished in April 2003.

The object of this collaboration has been the study of the behaviour of a 10 kW, 21-year old photovoltaic plant (first PV system connected to the public electrical grid in Europe).

A final report describing the aims of the MTBF project, the works performed within it, the obtained results and the conclusions that have been drawn after 3 years of analysis and monitoring is in preparation.

Regarding 2003, there are two important aspects to be put into evidence:

- I backsheet tedlar detachment from the aluminium layer. Detected in the bottom part of two modules in October 2002, this phenomena has been rapidly increasing (about 4 modules/month); in march 2003, 24 modules (9.5% of the overall plant) presented such a defect; at present they are 50 (19.8% of the overall plant).
In spite of the backskin detachment, the presence of the aluminium foil should avoid humidity penetration, hence delamination. On the other hand, the exposure of the aluminium foil could represent an electrical safety hazard, as the foil will - by capacitive coupling - be raised to a maximum potential above ground equal to the maximum system voltage.
- I substitution of the inverter unit. The LEEE-TISO is proceeding to the substitution of the ECOPOWER® 15 kW inverter, installed in 1992. It will be replaced by three Sunny Boy inverters (one connected to each sub-array). Modules previously removed from the plant (36 modules disconnected in 1992 because of the new configuration) have been recovered to complete the system (288 devices as was at the beginning).

Annual Report 2003

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

The "PV Enlargement project" is a multinational demonstration project coordinated by WIP (DE) and financed by the European Commission under the Fifth Framework Programme.

32 PV demonstration systems with an overall generation capacity of more than 1,150 kWp will be installed in 10 different European countries. The systems are either highly cost-effective or very innovative PV technologies.

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

The project will allow to compare the output of a large number of PV module technologies including several very innovative technologies on a quality level which was never realised so far, thus providing valuable results for the PV community and leading to an improvement of the competitiveness of the PV market and a cost reduction of the PV installations.

11 months have been elapsed from the beginning of the project and the most technical and non-technical preparatory work has been concluded successfully. The PV systems and data acquisition systems were defined for most of the partners and the first lot of data acquisition components is ordered.

The first installations went into operation during this year. By the end of 2003 over 50% of the total PV capacity to be installed within this project shall be operational and it is expected that the total PV capacity will be installed during the year 2004.

The performance tests executed by the LEEE-TISO laboratory will start in the following phase of the project.

Annual Report 2003

Langzeitverhalten von netzgekoppelten Photovoltaikanlagen 2 (LZPV2)

| | |
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| Project-Number | 39949 / 79765 |
| Duration of the Project (from – to) | 01.06.2000 – 31.08.2003 |

ABSTRACT

Purpose and Goals of the project during 2003

- € Update of HTI Burgdorf's monitoring visualisation software has been finished, including a new option (export of monitoring data in the format of IEA PVPS Task II, possible also for old monitoring data).
- € Monitoring data obtained in the monitoring projects of HTA Burgdorf can be converted automatically to the IEA data format. Therefore data from all PV plants with analytical monitoring have been supplied to the IEA database (>30 plant-monitoring years) and included there: <http://www.task2.org>.
- € Also internet access to the main data of the plants with analytical monitoring was realised. For on-line normalised energy production of the monitored PV plants: <http://www.pvtest.ch>.
- € Final report about this project with three amendments containing measured data in detail.

Most important results in 2003

- € Inverter reliability is equal compared to 2002 (4 defects were observed in older inverters that have been operated for several years).
- € PV plant Jungfrauoch (altitude 3454m), at the time of its erection the highest grid-connected PV plant in the World, has operated without problems (energy or data losses) now for over 10 years with an average annual production of 1372 kWh/kWp, referred to nominal STC-power.
- € PV plant Mont Soleil: Due to the detailed monitoring system of HTI Burgdorf, after a period of relatively low production around 2000 owing to a lack of sufficient monitoring, the reliability and the energy production of this plant could be increased again considerably and annual yields of 964 kWh/kWp could be obtained in 2002 and more than 1135 kWh/kWp in 2003.
- € Energy losses caused by inverter defects have been reconstructed with the new monitoring visualisation software of HTI Burgdorf.
- € Partial defects of the analytical monitoring system of Jungfrauoch and EBL Liestal were observed in 2003, but it was possible to reconstruct the missing data.

Annual Report 2003

Photovoltaik-Systemtechnik 2003-2004 (PVSYTE)

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| Project-Number | 100451 / 150557 |
| Duration of the Project (from – to) | 01.01.2003 – 31.12.2004 (31.12.2006) |

ABSTRACT

Purpose and Goals of the project during 2003

- € Development and successful tests of the new control software for the PV generator simulator 750 V / 40 A / 25 kW of the PV laboratory of HTI in Burgdorf.
- € Increase of measurement accuracy of power measurements by means of new high precision high-current sensors produced by LEM.
- € Validation of new test software by means of semi-automated inverter tests with known inverters.
- € Measurement of lightning withstand capability of thin-film modules.
- € Continuation of long-term monitoring of PV plants after end of former monitoring project LZPV2.
- € Participation in national network of competence BRENET (building and renewable energy network).

Most important results in 2003

- € The software developed now makes possible semi-automated tests of grid-connected PV-inverters (single-phase and three-phase) up to 25kW. 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. Power measurement accuracy on DC and AC could be increased considerably with new current sensors (50A).
- € Automated MPP-determination by means of curve fitting through V_{OC} and measured operating points on I-V-curve eliminates the need for separate measurements of P_{MPP} for each power level.
- € In order to get practical experience with the new test possibilities, several inverters (Top Class 4000/II, Top Class Spark and Solarmax 30 (three-phase)) could be tested much more thoroughly than ever before.
- € First tests with CIS-modules ST20 showed little sensitivity to simulated lightning currents owing to metallic backsheet. In future designs this metal sheet will be eliminated, therefore retesting will be necessary.
- € In 2003, the 10th anniversary of successful operation of PV plant Jungfraujoeh (1,1kWp, 3454m) could be celebrated. Analytical monitoring data from continuous, uninterrupted monitoring for more than 10 years are available now for several plants. Normalised annual data for 9 different plants are accessible on-line under www.pvtest.ch.
- € Monitoring data have been (and will be also in the future) made available to the IEA monitoring data base.

Annual Report 2003

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

6 different solar modules of two different suppliers have been measured to calculate the performance matrix. Different methods to calculate the performance matrix have been tested. Within the project, two different and simple methods have been evaluated to get best results:

- Outdoor-measurements analysed with PSI-Power-method.
- Outdoor-measurements analysed with King-method.

With these methods, reliable predictions of the results on energy rating of solar modules are possible. The measurements need to be very accurate. The minimal quality criteria of the measurement are not defined yet. Indoor-measurements also give very good results. But it's a time-consuming and expensive method, because around 100 flashes need to be done for each module.

The characterisation of a module is quite simple with these methods. With PSI power method, in addition to the power at MPP, 6 more variables are sufficient to characterise energy rating of the module:

$$P = P1 \dot{G}^2 + P2 \dot{G}^{3/2} + P3 \dot{G}^{4/3} + P4 \dot{G}^{5/4} + P5 \dot{G}^{6/5} + P6 \dot{f}_{amb} \dot{G}$$

The calculation is made with an Excel-program, and it's possible to calculate it on an ordinary personal computer. The same program also calculates the energy yield for a whole year (meteodata in one-hour steps) or for the standard days according to IEC-draft. With King-method, 6 variables in two equations are given:

$$I_{mpp} = a1 (G/1000) + a2 (G/1000) (T_{amb}-25)$$

$$U_{mpp} = b1 + b2 (\ln(G/1000)) + b3 (\ln(G/1000))^2 + b4 (G/1000) + b5 (T_{amb}-25)$$

To calculate these variables a special program is necessary, Excel is not sufficient. The uncertainty is not calculated.

The goal of the project, to find a simple method to characterise energy rating of a solar module, has been totally reached.

Annual Report 2003

INVESTIRE - Investigation on Storage Technologies for Intermittent Renewable Energies

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| Project- / Contract Number | ENK5-2000-20336 / BBW 01.0256 |
| Duration of the Project (from – to) | 7/01 - 12/03 |

ABSTRACT

INVESTIRE is a **NETWORK** of 35 European partners from 20 companies and 15 research centers which have shared their knowledge in order to review and assess existing storage technologies in the context of renewable energy applications

The main difficulty at the end of the project is to get objective information on all the technologies since the actors making the end reports are also specialists themselves of one of the technologies. The following report tries to take some distance from this oriented information to combine it with known external information in order to present the best objective information.

The main information, which we could guess at start, is that Lead-Acid remains today the only technology which can cover most of the applications using renewable energy. Lithium could become a real challenger, provided its price drops, if its problem of safety is resolved. Nickel with Ni-MH need improvements but the competition with lithium does not give it many chances. Metal-Air is not yet a real "rechargeable" battery, so its future for these applications is very much uncertain. Flywheels and Supercapacitors will probably never enter the renewable market for stand alone storage but could be of interest for stabilization of small grids using a large proportion of renewable sources. Electrolyser, Hydrogen Storage and Fuel Cell should remain a laboratory curiosity: H₂ fabrication and distribution is terribly inefficient, fuel cells feature a very limited life time together with an exorbitant price. But the lobbies of petrol companies and car manufacturers push so much that public money might continue to flow in to this no future technology. Redox Systems could play a role in small grids in the range of MWh capacity. The last technology, Compressed Air Systems, is probably the most promising and interesting for renewable applications and recent developments mainly in Europe show that more and more people are aware of this.

Annual Report 2003

The European Polymer Solar Battery EURO-PSB

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| Project- / Contract Number | OFES N° 02.0248, EU-contract N° 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.

Annual Report 2003

ECLIPSE: Environmental and ecological life cycle inventories for present and future power systems in Europe

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| Project- / Contract Number | BBW 02.0090 |
| Duration of the Project (from – to) | From 01.12.2001 to 30.11.2003 |

ABSTRACT

The research project ECLIPSE (Environmental and Ecological Life Cycle Inventories for present and future Power Systems in Europe), has been co-funded by the European Commission and the Swiss Federal Office of Education and Science (BBW). ECLIPSE has been carried out by seven research partners, i.e. Ambiente Italia (I – coordinator), Electricité de France (F), ESU-services (CH), University of Stuttgart / IER (D), Kema Nederland (NL), Vattenfall (S) and DLR Stuttgart (D) .

The main objective of ECLIPSE is to provide potential users with

- A coherent methodological framework, including application-dependent methodological guidelines and data format requirements related to the quantification of environmental impacts from new and decentralised power systems in Europe based on a life cycle approach,
- A harmonised set of public, coherent, transparent and updated LCI data on new and decentralised power systems, in a format which will make them comparable to existing data of other energy technologies, easily adaptable to local conditions and technological improvement and up-datable.

In total, ECLIPSE describes and analyses 100 possible configurations of five main emerging technologies for distributed power generation, i.e. photovoltaics (PV), wind, biomass, small combined cogeneration systems (CHP), and fuel cells. The results are given in a life-cycle inventory (LCI) database, containing both the overall results in terms of resource consumption and emissions over the whole life cycle and detailed information on unit processes. Overall, around 440 unit processes are included in the database. Each technology is described in a report, which presents results in detailed and transparent manner, highlighting the crucial parameters which influence LCI results. This high degree of transparency and the parametric structure of the database enable potential users to model and study other combinations as well, e.g. changing geographic and climatic conditions or using different technology parameters. The reports give guidance for the use of the data-base by means of hyperlinks both to the unit process data and to the complete example configuration results. As far as the latter are concerned, in the report, they are presented in terms of selected air emissions and energy resources. The complete database, the full reports and additional information are contained in the project website: <http://www.eclipse-eu.org>.

Annual Report 2003

SUNtool

A Sustainable Urban Neighborhood Modelling Tool

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| 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 km²). 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.

Annual Report 2003

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 PVSAT1. PVSAT 2 was an EU-Joule 3 – project, it was successfully concluded in 2001. A practical application was realised with Satwatch in Germany. There are two main differences respectively novelties compared to PVSAT1. First envisaged improvement is the more precise irradiance calculation by using reference values from ground measurements (the so called kriging method) and as new opportunities the use of the data of the new MSG satellite. The second main subject is the transfer of on site energy production measurements to the central data handling and storage system. Based on these available informations, PVSAT2 will establish a low cost, reliable and easy-to-use performance check of photovoltaic systems. It runs automatically and will not require regular personal support.

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.

Annual Report 2003

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

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| Project- / Contract Number | ENK5-2000-00332 / BBW 00.0364 |
| 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.

Annual Report 2003

Combined project on multi-user solar hybrid grids (MSG)

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| Project- / Contract Number | NNE5/483/1999 – BBW 99.0494 |
| Duration of the Project (from – to) | 01.01.2000 – 31.03.2003 |

The task of UNIZH, the team of the University of Zurich (Departement of Psychology, Division of Social Psychology) is to develop social strategies to introduce and manage MSGs (multi-user solar hybrid grids). The objective is to develop new social means to overcome the existing problems in using a multi-user solar hybrid grid with different renewable energy sources in a sustainable and environmentally friendly, resource saving way. This means, on one hand, to improve the knowledge about the users of hybrid systems and their consumption behaviour as well as the knowledge about their environmental consciousness and their social cohesion and on the other hand to overcome some of the social problems related to the fair distribution of electricity and its use in the time where 'renewable energy' is available and the others do not use it.

Annual Report 2003

Schweizer Beitrag zum IEA PVPS Programm, Task 1

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| Project- / Contract Number | 11427 / 150176 |
| Duration of the Project (from – to) | 1.1.03 – 31.12.03 |

ABSTRACT

The Swiss contribution to the PVPS Programme included:

- € **National Survey Report**, a summary of developments in the market and political areas. The report's data is integrated into the IEA's **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 Dintikon, Switzerland
- € Two **Task 1 meetings** in Basingstoke UK, and Uppsala, Sweden

Work still to be done includes:

- € Definition and collection of commercial data (**Value of Business**). Task 1 Members still have to be convinced of the importance of business (and not just technical) data.

Annual Report 2003

IEA PVPS Programm, Task 2 (Schweizer Beitrag 2003)

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| Project- / Contract Number | 14805 / 67820 |
| Duration of the Project (from – to) | 1. January 2003 - 31. December 2003 |

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. The actual activities of the task are (subtasks):

- € Maintenance of the existing IEA PVPS Performance Database and collection of new PV system data
- € Evaluation of PV Systems
- € Improving PV System performance
- € Sizing of PV Systems

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.task2.org/>).

This annual report gives an overview of the Task 2 main activities for the year 2003. Which where:

- € Two expert meetings
- € Distribution of the IEA PVPS Performance Database
- € Analysis of the data collected
- € Maintenance of the Task 2 WWW-Homepage
- € Implementation of new activities
- € Dissemination of results

Duration of Task 2 activities, phase II: 1999 to 2004

Submissions have been made to the Executive Committee of PVPS for the extension of Task 2 for another five years. A great number of the member countries are in favour of an extension. No decision has been made.

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

Annual Report 2003

IEA PVPS Task 3

Use of photovoltaic systems in stand-alone and island applications

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| Project- / Contract Number | 35550 / 85956 |
| Duration of the Project (from – to) | 9/01 - 12/03 |

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.

In Subtask 1, "**Recommended practices for managing the quality of Stand-Alone Photovoltaic systems**" represents the minimum technical knowledge that designers of large PV stand-alone systems should have. The report gives recommendations at two levels: Compulsive and Recommended for all the steps of design and realization of a large SAPV system.

In Subtask 2, "**Guidelines for monitoring Stand-Alone Photovoltaic systems : methodology and equipment**" gives the basic information for choosing and installing the right data measurement system for testing a stand-alone PV system.

"**Management of batteries to be used in SAPV systems**" presents all the techniques used by regulators to control the charge and discharge of a lead-acid battery. The reports gives indications on new ways of controlling which are different from the usual voltage measurement circuits.

Two other reports are in preparation on how to choose the right lead-acid battery and alternatives to lead-acid batteries for the storage function in SAPV systems.

"**Demand Side Management for SAPV systems**" presents ways of improving the efficiency of a micro-grid with the user participation in better choosing his loads and managing his use of electricity. The report gives indications on how to incite users to better understand the system and the possible usage of electricity.

Annual Report 2003

Swiss Platform PV Development Co-operation and Contribution to IEA PVPS Task 9

(Deployment of Photovoltaic Technologies: Co-operation with Developing Countries)

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| Project- / Contract -Number | seco RK V/HAFO/11141 |
| Duration of the Project (from – to) | October 1999 – December 2003 |

ABSTRACT

With the support of the State Secretariat for Economic Affairs (seco), this project provides the Swiss contribution to IEA PVPS Task 9 - Deployment of Photovoltaic Technologies: Co-operation with Developing Countries. The objective of Task 9 is to further increase the overall rate of successful deployment of PV systems in developing countries. This is being achieved by:

1. identification of existing information and experience
2. exchange of information between PVPS participants
3. exchange of information with and between target groups
4. workshops for and information exchange with donor agencies
5. development of Recommended Practice Guides based on existing information
6. improved techno-economic performance of PV in developing countries
7. identification of areas where further technical research is necessary.

In the course of the fourth project year, 6 recommended practice guides were published by Task 9.

Beyond the contribution to IEA PVPS Task 9, this project aims at:

1. creating a network of users involved in PV technology co-operation
2. increasing information and access to international initiatives
3. co-ordinating activities between different actors involved in the subject of PV technology co-operation

Based on the experiences of the previous 3 years, in the fourth project year, the focus was on the consolidation of the concept for a new Swiss government-industry platform for the promotion of renewable energy in international co-operation (REPIC). A consensus was achieved among 4 government agencies (seco, SDC, SAEFL, SFOE) to collectively establish such a platform.

Annual Report 2003

PV-EC-NET

Network for Co-ordination of European and National RTD Programmes on Photovoltaic Solar Energy

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| Project- / Contract Number | NNE5-2001-00201, BBW 01.0190 |
| Duration of the Project (from – to) | 01.01.2002 - 31.12.2003 |

ABSTRACT

PV-EC-NET (PhotoVoltaic European Co-ordination NETwork) is bringing together most co-ordinating institutions of the national PV RTD programmes of the member and associated states of the European Union. The main goal of PV-EC-NET is to increase the efficiency and coherence of the PV RTD programmes of the EU and the independent EU member- and associated states. PV-EC-NET is therefore collecting, analysing and disseminating the information about these EU and national PV RTD programmes.

With the goal to analyse and, where possible, improve, the efficiency of the EU and national PV RTD programmes, a benchmark of these programmes is part of the activities of PV-EC-NET. This benchmark also aims to identify successful strategies and their key features. Furthermore a SWOT (Strengths, Weaknesses, Opportunities and Treats) analysis of the European PV situation has been performed. Ultimately, the network aims to provide a common European PV RTD Roadmap, thereby benefiting the EC and national PV RTD programmes by strengthening the European PV RTD base and its impact on the European PV industry.

In order to increase the coherence of activities at as many levels as possible, the information is made available to all interested parties of the member- and associated states through several different means of communication, including a web site (pv-ec.net), a periodical and workshops.

The most important deliverables of PV-EC-NET are:

- € Web site and newsletters
- € Inventory of international networks and organisations
- € Report on tuning potential for PV RTD programming in Europe
- € Country summaries of PV RTD programmes and activities
- € Report on Benchmark Analysis
- € Report on SWOT analysis
- € Road map and recommendations

Annual Report 2003

PV-NAS-NET

Co-ordination 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 - 30.06.2004 |

ABSTRACT

The overall objective of the project is better co-ordination 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 report 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:

- € improvement of the coherence of the NAS activities and European RTD programmes on PV energy;
- € formulation of the recommendations for PV RTD programming in NAS and the EC.

Annual Report 2003

Photovoltaic- Facade Mounting System for Thin-Film-Modules

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

ABSTRACT

This Photovoltaic-façade project has developed a new mounting system which allows the use of thin-film-modules in facades.

Because most of the thin-film-modules use different types of encapsulation and glass other than modules with crystalline cells, the stability of the mounting system together with thin-film-modules must be well investigated. The Technical School of Engineering and Architecture Lucerne, has a test equipment which permits steady pressure on plates. Thus, plate or PV-module deformation at different pressures can be measured.

By using this equipment, several thin film modules were tested. These tests and additional investigations with a calculation program for plates showed that the necessary stability demands for ventilated PV-façades can be achieved.

Based on these investigations, the exact mounting concept for the fixation of different thin-film-modules on concrete-wall, masonry or metallic-wall has to be determined.

A pilot installation will follow.

Annual Report 2003

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 – April 2004 |

ABSTRACT

The project photovoltaic-alpur-roof contains the development and tests of a new roofing system for photovoltaic modules.

In 2003, a new test room was built, which enabled the checking of the roofing system in wet weather conditions with defined wind situations.

The Technical School of Engineering and Architecture Lucerne, also investigated the stability of the new roofing system.

The investigations are not yet completed. Until now, they show where the weak points of the system are and which solutions lead to a roofing system, that fulfill the requirements of roofing norms.

When all the tests have finished, necessary modifications will be made in accordance with the results obtained.

This will lead to the first pilot installation of the photovoltaic-alpur-system.

Annual Report 2003

Roof Integrated PV-system scout house Weiermatt, Köniz

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| Project- / Contract -Number | 100032 / 150050 |
| Duration of the Project (from – to) | April 2003 to April 2004 |

ABSTRACT

In 2002 the owners of the scout house Weiermatt in Köniz decided to refurbish the 14 year old inefficient heat pump heating system. The occasion was used to investigate options to integrate the use of renewables into the energy supply of the building, and to demonstrate that a significant reduction of (external) energy consumption is feasible without impairing the aesthetic appearance of the building. In the framework of a feasibility study a solution was proposed that integrates a PV-system on the eastern and western sections of the roof consisting of three distinct sections. For the middle section, thermal solar collectors were proposed, which would operate in combination with new heat pumps.

It is expected that the integration of the PV-system and the thermal collectors into the building will reduce its need of external energy to about one fourth.

This report relates to the PV-system. It was commissioned in April 2003, the thermal collectors in July. The installation was performed with the active help of juvenile scouts. This was considered as an important part of the solar part of the project, which aimed at increasing the sensitivity of especially young people towards a more responsible and sustainable utilization of energy.

In the framework of the R&D project a measurement and data acquisition system has been installed, comprising measurement of temperatures, irradiation, power and energy. The measurement of irradiation was regularly compared with data recorded at the nearby Swiss National Meteorological institute.

The performance data recorded so far are above expectations. For the first eight months, an average performance ratio of 79% has been recorded, which can be considered as rather high for a building integrated PV-systems.

Annual Report 2003

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 March 2004 |

ABSTRACT



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

- 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 m². The active solar area is 100m² 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.

Annual Report 2003

12.75 kWp Photovoltaik-Anlage Dachintegration Dorfkernzone Wettingen

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| Project- / Contract Number | 43850 / 83895 |
| Duration of the Project (from – to) | Februar 2000 –Dezember 2003 |

ABSTRACT

This report describes the second year of operation of the 12.75 kWp PV installation on the office building of Stöckli, Kienast & Koeppel, Landschaftsarchitekten AG, CH-5430 Wettingen, Switzerland.

After a surprisingly good first year (production of 11'788 kWh from installed 12.75 kWp), this was even topped by the just past year of operation (12'862 kWh).

Although the planned 'open house' day, in collaboration with the AEW Energie AG, member of ARO, and 'Elektrizitätswerk Wettingen' EWW, was postponed for one year due to a lot of '200-years Kanton Aargau' activities, already many positive reactions from neighbours and passers-by could be registered. Most often it was pointed out that it was advantageous that the whole roof was replaced with panels and not just a portion of it. The new look of the roof, albeit yet unfamiliar, was recognized as consistent and good looking.

A more representative poll will be conducted in the context of the open house day.

Furthermore, the visualisation panel as well as the system control and data logger could be commissioned throughout the year. With a particular focus on power saving components, a total power demand of not more than approximately 10 W could be achieved.

Annual Report 2003

Sunny Woods, Zürich Photovoltaik-Anlage in Blechdach integriert

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| Project- / Contract Number | 42203 / 82131 | |
| Duration of the Project (from – to) | 07/01 – 08/03 | |

ABSTRACT

The condominium "Sunny Woods" is located on a south-facing hill in a residential area of the city of Zurich. Mostly because of the new approach to design, taking into consideration architectural, ecological and energetic considerations into account, the building has already been widely published in different professional journals, but also in the general press. Until now, "Sunny Woods" has been visited by far more than thousand architects and engineers from Switzerland and from whole Europe. Also the project has been presented in many lectures and on different symposiums.

Energetically, the project "Sunny Woods" is characterized by the following specifications:

- The insulation of the four-story wood building is outstanding. For example, the following u-values are achieved: façade 0.17W/mK, roof 0.11W/mK, windows 0.9W/m²K (glass 0.6 W/m²K, wood frames insulated partially with vacuum-insulation).
- The electrical power, which is produced by the pv-modules on the roof, should match the amount of power needed by the heat pump for heating and warm water.
- The roof of the building is covered with industrial aluminum sheet panels. The roof has a simple rectangular form and is slightly sloped to the south. It isn't shadowed by other buildings or trees. The roof is completely covered with 504 standard pv-modules of Unisolar-Beckert, which utilize amorphous, triple junction silicon solar cells with a rating of 32Wp.
- Each of the six photovoltaic-units with 84 modules and a Fronius pv-inverter is connected to the grid of the local power company. The maximum power provided by one pv-unit is 2'688Wp, so for the six apartments a total rating of 16'128Wp can be achieved.
- The installation of the pv-roof was very easy and could be completed in a very short period. The plugged electrical connections of the waterproofed junction boxes and the clipped mechanical connections of the panels to the roof saved a lot of time during the installation the roof.

The main goal of the P+D project is to control the efficiency of the complete chosen energy system.

Annual Report 2003

Integration en toiture plate CPT Solar

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| Project- / Contract Number | 100493 / 150604 |
| Duration of the Project (from – to) | From 1.8.2003 to 31.12.2006 |

ABSTRACT

The goal of the project is to analyse the behaviour and the energy yield of a 15.4kWp PV system based on flexible triple-junction thin-film amorphous silicon modules incorporated into a flexible polyolefines (FPO) membrane which acts as waterproofing system of a flat roof.

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.

A flat roof of a surface of 960m² has been recovered with the single ply roofing system based on flexible polyolefines (FPO) membranes laminated together with UNI-SOLAR flexible modules. The 15.4kWp power plant is composed of three inverters SB5000TL with three independent MPPT capable inputs each. To each inverter four strings are connected in a 2+1+1 configuration. Each String is composed of 5 Sarnasol-PV modules, each Sarnasol-PV module of two 22-L-B Uni-Solar laminates.

The mechanical characteristics and the reliability of the flexible polyolefines membranes has the right characteristics to be combined with 22-L-B (UNI-SOLAR) amorphous silicon triple-junction modules. The modules are laminated on the membrane which is directly put on the roof. The membrane is joined to the roof structure by means of hot air welding and then mechanically fastened.

The thermal insulation of the roof is 120 – 186 mm thick, and the single elements has an inclination of 3° allowing the rain water to flow away. The thermal insulation does not allow a ventilation of the modules as usually requested by crystalline silicon PV modules. This leads to a heating of the modules and consequently to changes of the operating PV parameters. The project will include monitoring of major meteorological parameters (ambient temperature, irradiance, wind speed and direction) and system parameters (PV module temperature, voltage and current, etc.). For inter-comparison reasons near to the main PV plant 3 small open-rack plants with a-Si and c-Si will be installed. In the past an improvement of the energy yield could be observed caused by the thermal insulation of one string of an a-Si (single-junction) installation situated on the roof of the LEEE-TISO laboratory. One of the goals of the project is 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.

Annual Report 2003

16.3 kW Installation with Thin-Film-Elements on the Flat Roof at the CNB-Building of the ETH

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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 in the city center. The building has to be renovated and as a part of the renovation a new photovoltaic installation will be realized. The building is subject of local historical monument preservation and protection codes. Therefore, the PV-modules will be fixed with a small inclination (3°), so that the whole installation will not be visible from below. The installation will have a power of 16.3 kW peak and will consist of standard frameless thin-film-modules. The service of a PV-installation with amorphous tandem-cells shall be demonstrated at the ETH center in Zurich.

A display in the new cafeteria will provide information about the service of the installation.

The realization is planned for 2005, together with the roof renovation work.

Annual Report 2003

62 kWp PV-Installation Flat Roof Integration with PowerGuard Tiles

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| Project- / Contract Number | 100154 / 150196 |
| Duration of the Project (from – to) | April 2003 – December 2004 |

ABSTRACT

In Triengen, Switzerland, the Trisa Electro AG is building a new logistic center. A 62 kW photovoltaic installation will be integrated in the flat roof of this building.

The used PowerGuard-tiles consist of a combination of insulation elements and frameless photovoltaic modules. Therefore, the installation, which is planned to be realized in December 2003, will produce electrical energy and will reduce the energy needed for heating the building.

The data acquisition system and the information display panel at the entrance of the logistic center shall show the function of this building-integrated PV-installation.

Annual Report 2003

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, furnish 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.

Annual Report 2003

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. dp.) particularly for flatroof solarplants. **AluStand**® exhibits the same main features as the AluTec - System:

- ## Easy project planning with statements about stability against wind power and about plant dimensions and costs
- ## Modules mounting without use of any tools
- ## 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 gain of working time using the **AluStand**® - system
- ## Testing of the resistance against wind power
- ## Verification of the useability of the new developed projecttool with statements about 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 in the middle of the year 2004. Subsequently the results and conclusions of the project will be published in the final report.

Annual Report 2003

Installation photovoltaïque à Palexpo

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| Project- / Contract Number | 45736 / 85795 |
| Duration of the Project (from – to) | 1.7.02 – 31.12.03 |

ABSTRACT

A 70 kW photovoltaic installation has been constructed on the roof of the new Hall 6 of the Geneva Palexpo, a complex that hosts various conferences, exhibitions and sporting or other events, counting almost 1.5 million visitors a year, including the International Car Show, which alone attracts more than 700'000 visitors each year.

The purpose of this installation is the indirect supply of recharging terminals for electric vehicles.

The solar installation and the electric vehicle recharging terminals support an information campaign on solar energy and "sustainable" transport.

For this purpose various explanatory signs have been placed inside the Geneva Palexpo halls and a promotional stand for renewable energy and "sustainable" transport was placed inside the International Car Show 2003. This stand had some success: more than 4'000 people took part in the competition organised on this occasion.

Annual Report 2003

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 modules 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.

In the project we tried to measure and quantify the influence of an increased cooling effect on the back of the module, due to the new construction of SOLGREEN, which is higher above the ground than standard mounting systems. A better cooling effect thanks to higher wind speeds, is resulting in a improved module performance hence higher energy output. It was found that other factors, like module mismatching and the inverter efficiency and performance have a higher impact to our measurements. Thus it is difficult to quantify the improved module performance thanks to the new mounting system.

Our wind speed measurements have indicated no critical impact to the mounting system. SOLGREEN was designed for wind speed higher than 20 m/s and meeting the wind load requirements of 120 kg/m². But so far we did not measure wind speed higher than 20 m/s in the project and thus the mounting system was never really tested close to its limits.

In 2004 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

Annual Report 2003

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 2003, the project „Autonomous Energy Supply by Photovoltaics and Fuel Cell“ had the following focus

- ## evaluation of the components for the energy supply
- ## acquisition of the fuel cell
- ## acquisition and start of the operation of the system manager and control unit for the connection to the fuel cell
- ## testing and start of the operation of the data recording by the system manager
- ## installation of a test set in the laboratory of the Bundesamt für Landeshydrologie (BWG)
- ## evaluation of test sites for the field tests of the Bundesamt für Landeshydrologie (BWG)
- ## first presentations for expert groups at a fuel cell-symposium in Germany
- ## presentation at the electronics fair Ineltec in Basel 2003

The open points could all be settled. The objective is an energy supply that is reliable as well as suited to series installations. The selected fuel cell is a compact methanol fuel cell of small power (25 W). For the system manager a good solution close to practice could be found. For this purpose a TAROM system-manager by Steca (D) is used which we also use for medium-size PV installations. Two conventional solar energy installations are fitted with this controller for reference purposes.

At the same time suitable test sites have been evaluated for field tests, and sites in the Canton of Ticino, in the central and eastern parts of Switzerland have been identified.

Information activities started in the middle of 2003. As expected the interest has been remarkable. The price for the fuel cell turns out to be the main barrier.

Annual Report 2003

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 save 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 3.9 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 2003, the performance of the PV-plant has been analysed. The actual monthly energy yield has been compared to estimated values based on solar irradiation. 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. First calculations show for the CIS Plant good results of power STC.

Furthermore we interviewed staffers of Würth Holding concerning her aesthetics impression of the semi-transparency modules. The reaction of respondent persons were mainly positive.

In 2004, investigations will be focused on performance measurements for individual modules. To detect all sorts of degradation, performance matrix will be compared.

Annual Report 2003

PV St.Moritz Corvigliabahn Piz Nair

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| Project- / Contract Number | 45674 / 85734 |
| Duration of the Project (from – to) | Dec. 2002 - Sept. 2004 |

ABSTRACT

Photovoltaic systems on alpine sites above 2000m can produce, depending on the topological situation, significantly more power than anticipated. Reasons are the Albedoeffects (reflected light in addition to the direct sunlight) and portions of diffuse light. When sizing such installations this wishful increase in input power has to be taken into account. In order not to lose valuable energy due to power limitations sufficient oversizing of the inverter is needed.

Both installations, Corviglia and Piz Nair (3050 m) can profit from Albedoeffects, especially in winter and early spring months. The main goal of the two projects Corviglia (17.8 kWp) and Piz Nair (13.53 kWp) is to gain more information on the Albedoeffects under alpine conditions. The results will be of high value for the development of new projects. Both installations will become eyecatchers for tourists of the famous St.Moritz area. Especially the Piz Nair façade fascinates thanks to the perfect integration of PV into modern architecture.

In May/June 2003 a further PV-System was installed on the south oriented façade of the lower Piz Nair-Station. Nominal power 9.7 kWp. Also this installation profits in the winter months from additional sunpower reflected by the opposite slopes. Beginning of March 2003 irradiation values of up to 1.4 kW/m² were measured on the vertical plane of the south façade. Therefore it will be of interest to compare the results with those of the other installations.

Annual Report 2003

PV-Obelisk

Information system in the public sector

| | |
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| Project- / Contract -Number | 45574 / 85634 |
| Duration of the Project (from – to) | 1 st June 2002 to 1 st June 2003 |

ABSTRACT

A power supply with photovoltaic (PV) for non-building structures is known for parking ticket machines, emergency signals and others. Today several products are available but many lack an overall design and well thought concept incorporating PV and the application and the aesthetics. The innovative approach of this project 'PV-Obelisk' is the combination of PV in an aesthetic way with a multi-functional pillar made of natural stone. PV serves as power supply and as design element to influence users in a positive way.

A first prototype was build to give a first impression of the concept. The company Hess Naturstein AG constructed the 1:1 model without electrical consumers. This Obelisk gave suitable and precious inputs and insights for the further development. Then prototype 1 was ready in November 2002 and incorporated three LCD-displays, which could be activated directly via SMS with commercials or other information. This function independent of the location and time was an important goal and enhances the universality. We received mostly positive reactions for the design and the concept from the industry and the public sector. Over a period of 6 months the PV-Obelisk was tested at the Migros in Volketswil and presented to the interested parties. Based on an intensive survey, one of the results showed that the cost-use-factor was not market acceptable.

In July 2003 the second prototype was constructed. From the market survey a optimised consumer configuration was planned, to guarantee a maximal user ratio. The test operation in front of the highway restaurant Heidiland confirmed the market analyses and delivered the expected results. The product proved its technical reliability and showed a high user factor. Because of the high overall energy consumption it was only possible to apply PV as a part energy supply. Different compromises had to be taken in technical and aesthetic aspects, for the sake of a market acceptable product. After this P&D project the type 2 will be introduced in the market. For the year 2005 a production of 10 pieces is feasible and for the coming years we calculated 10 per year too.

The PV-Obelisk can be apply as a whole concept for non building structure in the public area. Bench, info terminal to water fountain system can be covered. The industry is asking for eye catcher to get a message easily over to the consumers, but these are often a 'thorn' in the eye of the public sector. It is important to work closely with the public sector from the beginning. One has to consider the need of the urban planners and come up with overall solutions and not only with one specific product.

Thanks to a very engaged co-operation and good participation of all parties the project could be successfully finished according to the goals. In 2004 the PV-Obelisk will be introduced in the market und will carry out promotion for PV too.

Annual Report 2003

Monitoring of the 16.8 kWp PV-plant with CIS modules in St. Moritz

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| Project- / Contract -Number | 41239, 81207 |
| Duration of the Project (from – to) | 1 May 2001 – 31 August 2003 |

ABSTRACT

The monitoring of the 16.8 kWp grid-connected PV plant with CIS (Copper Indium diselenide) modules, situated on the roof of the Ludains ice rink in St Moritz, is finished.

During the 2 years of monitoring (September 2001 – August 2003) the plant produced, without any days of failure, 35'084 kWh (1044 kWh/kW) with a daily peak of up to 88 kWh. The energy production of this plant could be even more, if some strings, especially in winter, would not be partially shadowed (~3%) and if the inverter sometimes would not go in overload (~2%).

The high and stable efficiency ($PR=0.81$) of this CIS plant is also confirmed from the final outdoor I-V characteristics measurements.

The measuring equipment has been dismantled and it would be use for the detailed monitoring of another PV-plant (CPT SOLAR – 15 kWp OEM a-Si triple junction modules on a Sarnafil T waterproofing mantle).

Annual Report 2003

PV-Anlage Dock E vormals Dock Midfield Zürich Flughafen

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| Project- / Contract Number | 37006 / 81193 |
| Duration of the Project (from – to) | 1.2.2001 - 15.12.2003 |

ABSTRACT

The new terminal building Dock E (formerly Dock Midfield) at Zurich airport has been completed November 2002, and began normal operations in September 2003. Since April 2002 the 290-kW-photovoltaic-plant on top of the building works without problems. The produced electricity has been reported since the beginning of the plant operation. The energy gained is well above the expected values and clearly above the mean value of Swiss PV power plants. On one hand, this is due to the sunny summer 2003. However, it is also a result of optimal plant design, a very good power output of the delivered PV-panels and high efficiency inverters.

The photovoltaic plant is integrated in the pergola-roof of the building. It has, besides the production of renewable energy, two other functions: As an important element of the building's architectural design it gives the building it's appearance and forms the roof. Secondly, the pergola with the PV-elements shades the south facade at the attic level, where the lounges are located.

Because of its attractive part of the architectural design and the optimal integration in the building, the plant won the Swiss award "hommage solaire" 2002, in the category of best integrated plants.

This installation is also part of the European research project PHOTOCAMPA: PV grid connected system in parking and roof, 5. EU-framework program. A part of the plant is measured following the guidelines of ISPRA research centre.

Annual Report 2003

SolarCat

Solar-Electric Passenger Ship

| | |
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| Project- / Contract Number | 36407 / 77803 |
| Duration of the Project (from – to) | June 2000 - December 2002 |

ABSTRACT

The project SolarCat includes engineering design, construction and operation of a solar-electric powered passenger ship for inland waterways. The ship named "MobiCat" is of the catamaran type and has a length of 33 m and a width of 11 m. The electric energy is produced by an array of 20 kWp of photovoltaic panels and stored in two lead-acid batteries of 480 V and 240 Ah each. The ship is powered by two 81 kW industrial AC drives. With a passenger capacity of 150 persons MobiCat is the largest solar-powered ship worldwide.

The ship was inaugurated and put into service on July 6, 2001 in Biel/Bienne, Switzerland. Since then the ship has transported about 14'000 passengers and achieved a total distance of nearly 6000 km. Since July 2001 the main characteristics of the ship are being measured and recorded by means of an onboard data collection system. The measured data were analysed in order to obtain detailed information of the energy-related behaviour of the ship. In particular, the energy balance of the 2002 summer season was calculated.

The operation experience is generally positive and the project has attracted wide interest both by the public and the media. Therefore the MobiCat has become the most popular charter ship on the lake of Biel/Bienne.

The project was financed largely by sponsors, mainly by the insurance company Schweizerische Mobiliar, the utility BKW-FMB Energie AG and the watch company Certina. The Swiss Federal Office of Energy is co-funding the project as a pilot and demonstration activity. The remaining costs are borne by the navigation company of the Lake of Biel/Bienne, BSG, the owner and operator of the ship. Data collection and evaluation is being sponsored by the Société Mont-Soleil.

The ultimate goals of the project - to demonstrate the feasibility of large solar-powered passenger ships and to present new solutions towards sustainable mobility on inland waterways - have been fully reached.

Annual Report 2003

Amburnex Solar Farm

3 kWp

| | |
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| Duration of the Project (from – to) | 1999 - 2003 |

ABSTRACT

2003 has been characterized by some disturbances due to breakdowns; caused by the diesel generator which was out of order for several weeks. The inverter also had some problems assuming the peak-power during the morning hours.

For next season, we intend to separate the engines that need high power from the grid. They will be directly connected to the generator. Hence, the batteries will be able to provide electricity for the remaining energy need without peak-power problems.



Annual Report 2003

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 2003, Resurgence has started the realisation of the PV projects. In Holland and Switzerland, all planned projects are realised, in the other countries there are still some projects which are not finished so far. Informations about the installations and other documents created in this projects can be found on www.resurgence.info.

The goals for 2003 have not overall been achieved as some installations are still not operating. They will have to be built in 2004.

In 2004, monitoring, dissemination and social integration will be the main work tasks to be done.

Annual Report 2003

Installation photovoltaïque autonome 3,1 kW

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| Project- / Contract Number | 100'139 / 150'172 |
| Duration of the Project (from – to) | July 2003 to July 2004 |



ABSTRACT

The PV system of the family Blattner in Soyhieres (JU) is one of the biggest stand-alone photovoltaic installation of Switzerland.

The stand-alone hybrid system is using solar slates (Sunslates™) for the PV production and is connected to a Diesel generator. The PV system (3,1 kWp) is integrated in the roof annex of the Family Blattner farm producing biological wine in Soyhières.

The measurement campaign has started in July 2003 and will last one year.

Annual Report 2003

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

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 2004. Based on this, the evaluation of the first measuring period can then begin.

Annual Report 2003

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 shows the monthly different performance ratios between March 2003 and November 2003, related to the performance ratio of the reference. It has been shown that the differences between thermal insulated modules and modules with free back air flow are in parts significant: Whereas two module types are more efficient with free back air flow (ST40, US64), two module type yields significantly the same (DS40, BP850) and one module type more energy (K58) with thermal insulation. Broken modules in the PV arrays allows not to make a conclusion concerning the temperature behaviour of the module SG30.

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

The results presented here are provisional kind and must be in future confirmed by later conducted detailed evaluations. In addition, we expect more detail-information about the modules and their operational behaviour from the manufacturers, which will then flow into later evaluations.

Annual Report 2003

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) | 2002-2004 |

ABSTRACT

The 100 kW AET III grid connected PV plant is located along the railway in Riazzino. It 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).

The purpose of this project is 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 analysed for 2 years: since the renovation the plant is working properly. Its PR now exceeds 70% (right from 70W/m²), and it is better with respect to the one of previous years.

Considering only the **first 11th** months of the year 2003, the plant has produced 109.627 MWh, production never reached in 10 years of operation (maximal production 98.5 MWh in 1999, average 91.8 MWh). This is due to the particularly favourable meteorological conditions ($H_i=1'529\text{kWh/m}^2$ in 11 months), and also due to the excellent performances of the new converters. This energy yield ($Y_f=1'049\text{kWh/kWp.y}$) clearly exceed the production estimation of 95-100 MWh.

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 106.0 W, therefore the total estimated field power @STC is 91.6 kW. This value is still 11.4% 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 ($\pm T$ up to $+30^\circ\text{C}$). One new module with malfunctions and one with broken glass were found. However the plant doesn't show any relevant or serious thermal problem. The conformation of the ground affects the ventilation and consequently the modules operating temperature ($\pm T$ up to 10°C).

Annual Report 2003

Newtech – Vergleich 3 x 1kWp Dünnschichtzellenanlagen

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| Project- / Contract Number | 43849 / 83893 |
| Duration of the Project (from – to) | 01.04.2001 – 30.09.2003 |

ABSTRACT

Purpose and Goals of the new project

Comparison of the operation and energy yield of 3 grid connected 1kWp-photovoltaic plants with different thin film solar cells-technologies (a-Si-triple-cells, a-Si-tandem-cells and CuInSe₂-cells). The 3 PV plants are at the same location and each of them is operated with an own, identical inverter (ASP Top Class Spark). The PV plant and the monitoring system operated successfully since 17.12.2001

Newtech 1 with CuInSe₂-(CIS-) Cells :

In 2002, with 1091 kWh/kWp and in 2003, with 1259kWh/kWp this plant had by far the highest specific annual energy yield of all PV plants (including mono-c-Si and poly-c-Si) in Burgdorf. The operating behaviour of this technology seems to be similar to that of crystalline Si-cells. Especially good is the fact that with these modules measured STC-power was considerably higher than the nominal power indicated by the manufacturer.

Newtech 2 with tandem cells of amorphous Si :

In 2003, the energy yield of this plant (1037 kWh/kWp) was again the lowest of the three Newtech thin-film plants. Energy production at low irradiance levels is relatively low. Under such conditions, the output voltage drops considerably and then the inverter operates outside of the MPP despite the relatively wide input voltage window. Cell efficiency is relatively low, moreover during the winter months module power has degraded considerably, but during the very hot summer 2003 the module power recovered mostly, but not completely.

Newtech 3 with triple cells of amorphous Si :

In 2003, with 1102 kWh/kWp this plant was again also among those with the highest energy yield in Burgdorf. This plant has a relatively high performance ratio PR at low irradiance levels. Seasonal degradation and recovery behaviour was similar to that of plant Newtech 2.

Annual Report 2003

Beschichtung von PV-Modulen

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| Project- / Contract Number | 35527 / 75305 |
| Duration of the Project (from – to) | Sept. 1999 - Jan. 2004 |

ABSTRACT

Purpose and Goals of the Project:

To quantify the effect of different PV-module coatings on:

- ## cost reduction on cleaning expenses (less frequently, less detergent, etc.)
- ## positive effect on long-term degradation
- ## increase of module efficiency due to improved transmission

The project is performed as two parallel investigations: laboratory investigations for a systematic screening of different glass/coating combinations and a "real term" investigation in an existing power plant. One of the coating/glass combination agrees with the combination tested in the "real term" investigation, so that results can be compared and laboratory data can be interpreted into real data.

Most important results in 2003:

Laboratory investigations:

At the end of the third year, there is now a large number of data available for different coating/glass combinations with either two or three years of exposition. The different exposition time is due to material problems of the original set in the first year. It was necessary to order and prepare a large new batch for exposition (see report 2000). Since it is the target to identify long term effects, it is still too early to draw safe conclusions.

"Real term" investigations:

Three years of measurements have been collected and evaluated. The data acquisition system has proven its reliability and the data is of high quality. The coatings show a slight tendency to improve the efficiency of the PV-panels. Nevertheless, it's too early to draw safe conclusions. It is currently discussed if the measurements could be financed for another four years.

Annual Report 2003

100 kWp PV-Netzverbundanlage A13 Messkampagne, Periode 2003

| | |
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| Project- / Contract -Number | 32046 / 71920 |
| Duration of the Project (from – to) | Jan. 2003 - Dec. 2003 |

Abstract

13 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-term behaviour of a large grid connected 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 and 2003 some minor but important components of the inverter unit failed. The components, which failed, were mainly electromechanical devices with moving parts and the faults were not always easy to find. In the year 2003 53 % of the available energy was lost due to non-operation of the inverter.

In the night of the 14. of June 2003 96 modules were stolen from the plant. The plant remained operational.

In the year 2003 the plant produced 58'978 kWh or 567 kWh/kWp with a performance of 38 % and an availability of 50 %.

In the year 2004 it will be decided if the inverter will be repaired or replaced with a new type. The 96 stolen modules will be replaced.

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

Annual Report 2003

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 photovoltaic also needs practice-friendly installation standards for safety and increased application. A well applicable installation standard helps to prevent from electrical accidents and damages to property (fire). Switzerland as an IEC- and CENELEC-member has to take over the new standard IEC 60364-7-712.

The existing, more than 10 years old provisional national PV-safety regulation 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, easy to apply for both, installers and PV-experts. 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 group of cores has worked out the basic document. An enlarged group of experts secured the wide support and during a workshop the PV-branch was given the opportunity to express its opinion.

The new standard reached a high acceptance. The course of the project fulfills the according schedule.

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GISS Gebäude-Integrierte Solarstrom-Systeme (Building Integrated Photovoltaic BIPV)

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100141 / 150173

Duration of the Project (from – to)

Juni 2003 – Mai 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 constructors 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.

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Solar *Electri* City Guide

Schweizer Solarstromführer für die Gemeinden

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|-------------------------------------|--|
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| Project- / Contract -Number | 100627 / 150824 |
| Duration of the Project (from – to) | 01.07.2003 - 30.06.2004 |

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 spring 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) with the necessary information and instruments to define, evaluate, plan and implement PV projects in an urban environment. The focus is on municipalities and local implementation.

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 is currently translated and 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 to be published during 2004.

Annual Report 2003

REMAC 2000

Renewable Energy Market Accelerator 2000

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| Project- / Contract -Number | NNE5-2000-00012, BBW 00.0088 |
| Duration of the Project (from – to) | 01.11.2000 - 31.10.2003 (follow-up) |

ABSTRACT

The purpose of the REMAC 2000 project was to identify policies and strategies that are suitable for accelerating the growth of renewable energy (RE) markets in the European Union member states and world wide. This aim was pursued through a co-ordinated series of activities, which also engaged senior decision makers from public administrations and the RE industry in exploring new market stimulation initiatives.

The project was carried out by a team of experts from CESI (Italy – co-ordinator) and its subcontractor Ecobilancio, NET (Switzerland), ECN (The Netherlands) and CNRS-IEPE (France), with sponsorship from the European Commission, the International Energy Agency (IEA), the Swiss Government and the RE industry (BP Solar). The project was therefore also a demonstration of closer working between the European Union, the IEA and the RE industry on the development of guidelines for enhancing the EU and global markets for renewable energy.

As building blocks, the project team collected the most recent data on RE technologies, markets, and costs. The project also explored the implications of the major changes and restructuring that had been taking place in the RE industry and in energy markets during the past few years. These changes, together with the emerging activities and mechanisms from the Kyoto Protocol, are expected to have significant impacts on future growth of RE markets. The project reviewed the extent to which all these changes and mechanisms had been taken into account in the existing models for forecasting future RE markets. Gaps or uncertainties were identified, and recommendations made for how to address these aspects in the future.

Lastly, the project developed a road map, namely a list of priority policies, key intervention areas and actions needed to accelerate the market growth in order to attain the targets deemed as feasible over the next 20 years.

In a follow-up and in co-ordination with the International Energy Agency, a report has been developed and published as a book entitled "Renewables for Power Generation - Status and Prospects".

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Quality in the Photovoltaic Sector

| | |
|-----------------------------|--|
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| Project- / Contract -Number | DIS 17967/57555 |
| Duration of the Project | 2001-2003 |

The project elaborated all relevant quality issues related to "PV Certification", such as:

- (i) Defining training courses for PV electricians and installers (sub-project 1) and,
- (ii) Elaborating manufacturing and quality assurance standards for PV products, systems and services (sub-project 2).

In several European countries, publications, training material and courses were implemented for harmonising the European PV sector with Global PV standards initiatives. Within the project, the following results were achieved:

- (i) How to implement a Quality Management System (QMS) (ISO 9001:2000) into a company. A manual for the implementation of a QMS and indicating the benefits has been elaborated that is now available in English, French, German and Spanish.
- (ii) Standards and regulations are available on the national, European and international level for the PV sector. However, there are still standards lacking. For this reason a list of PV Recommended Specifications (PVRS) is prepared and available.
- (iii) Accredited test laboratories are allowed to test PV components, mainly PV modules.
- (iv) The project resulted into accrediting training courses and facilities. According to the national and international standard.

Finally, the database published on the website www.pv-quality.org provides information on certified products, services and training.

The following companies and organisations have been contributing to this project: WIP, Alpha Real, EC-JRC, ECN, ISPQ, IT power, ADEME, European Photovoltaic Industry Association (EPIA), TNEI and PV GAP. The project was co-financed by the European Commission and the Swiss Government.

Annual Report 2003

IEC Normenarbeit für PV Systeme

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| Duration of the Project (from – to) | 2002-2003 |

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.

Present work: TC 82 has seven working groups developing standards for the photovoltaic industry. Some of the topics these various groups are working on include: solar simulator requirements, design qualification and type approval of Solar Home Systems, safety of inverters and charge controllers, islanding prevention measures for grid connected PV Systems, and design qualification and type approval for concentrator photovoltaic receivers. 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.

Future work: In the future, TC 82 expects to address several system and component safety issues including grid-connected systems on buildings and utility-connected inverters. Also, a new working group is planned which will deal with various aspects of environmental protection; i.e. safeguarding the natural environment from such things as RF and electromagnetic pollution, disposal of toxic PV materials, atmospheric contamination from PV manufacturing processes, etc.

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.

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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. In the next few months, an English and a French version will follow.

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Photovoltaic Energy Statistics of Switzerland 2002

| | |
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| 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 the year 2002 in Switzerland were only 75 new grid-connected PV plants connected to the grid, as few as since seven years no more. Although the plants feature larger power from year to year, the Swiss PV Market stagnates further. This in contrast to the world-wide development, where the market of this future technology grows irresistible.

It was shown, that the annual average yield of all PV installations in Switzerland is just under 800 kWh/kWp, changing slightly from year to year due to changing irradiation and other effects. The systems overall reliability and operational availability is with around 98 % still considered very good for technical systems.

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Solarstrom vom EW

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| Duration of the Project (from – to) | Seit 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 seven years of operation, this action has achieved remarkable results: More than 130 utilities participate in the action as of end of 2003, 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 5.5 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.