June 2001

Photovoltaic Programme Edition 2001

Summary Report, Project List

Annual Project Reports 2000 (Abstracts)

elaborated by:
NET Nowak Energy & Technology Ltd.

BFE OFEN UFE SFOE

Title page:
6 kWp system with semi transparent modules, Unterseen
Photo: NET Ltd.

elaborated by:
NET Nowak Energy & Technology Ltd.
Waldweg 8, 1717 St. Ursen (Switzerland)
Phone: +41 (0) 26 494 00 30, Fax. +41 (0) 26 494 00 34, Email: mail.net@bluewin.ch

on behalf of:
Swiss Federal Office of Energy
Worblentalstrasse 32, CH- 3062 Ittigen postal addresse: CH- 3003 Bern
Phone: 031 322 56 11, Fax. 031 323 25 00, office@bfe.admin.ch www.energie-schweiz.ch

PHOTOVOLTAICS

Summary Report Edition 2001

Concerning research program 2000

Stefan Nowak
stefan.nowak.net@bluewin.ch

Symbiosis between architecture and photovoltaics in a historic town centre

6 kWp system with semi transparent modules, Unterseen;
Project management: Industrielle Betriebe Interlaken; Architect: Mario Campi;
Engineering photovoltaic system: Fabrisolar;
Photos: NET Ltd.

Contents

1. Program summary and targets for 2000

The photovoltaics (PV) program in 2000 was characterised by continuity of national projects having an implementation bias, and by a continuing high-level of international cooperation. Cooperation with industry was once again intensified. Especially noted is the progress made in the technology transfer of thin film solar cells, and for several projects, this has taken on more concrete form. Despite general disappointment in the wake of the negative outcome of the national plebiscite of 24 September 2000, interest in photovoltaics on the part of industry and the financial sector has remained intact. Over the period covered by this report, more than 80 research and P+D projects were active (this figure includes all known projects, irrespective of funding). In total, the number of projects remained of the same order as last year, while funding showed a continuing upwards trend.

The five program sectors comprised the following themes and objectives:

Cells: Work on thin film solar cells continued during the report period, the emphasis being on **silicon** (amorphous, microcrystalline, low bandgap), cells based on compound semiconductors (CIGS, CdTe) and dye sensitised cells. In all these technologies, increased efforts towards implementation were made and – together with industry – new process-oriented projects commenced. Thanks to these activities, the option 'solar cells made in Switzerland' is beginning to take on visible form. A range of substrates is destined for application in niche markets.

Modules and building integration: The **integration of photovoltaics** in the built environment continues to be a major focus in the development of applications. A number of new products were able to establish themselves on the market during the report period, and these are increasingly finding export outlets. Attractive and high quality design and competitive prices are central features of these systems. Many systems have now been successfully integrated into existing applications, and further improvements in the cost situation have been achieved. New concepts (e.g. PV insulating glass) continue to find practical application. In connection with the anticipated increase in the use of thin film cells, further steps will be needed in future to introduce these into more advanced system configurations that combine the functions of solar module and building component.

Systems technology: In view of the progressive market developments taking place in photovoltaics, the significance of **quality assurance and standardisation** will continue to expand. At the component level, yield and reliability will improve based on experience of earlier designs. New products will profit from the broad experience gained in past years. Correctly planned and professionally built, photovoltaics installations can reliably produce energy over long periods of time. Simple quality assurance procedures – not least for technical reasons – are therefore called for.

Other projects and studies: The need for **combined uses** of photovoltaics (e.g. hybrid technologies, thermo-photovoltaics) is frequently voiced. Here, however, not just technical feasibility, but also market relevance and profitability must be considered. The objective in future will be to provide improved quantification in this respect. Advanced **tools** (i.e. for insolation, horizon profiling, dimensioning and simulation) are now well acknowledged, and these must further establish themselves in national and international markets.

International cooperation: International cooperation forms the mainstay in all sectors. Participation in international developments and an intensified exchange of information within the international **EU** and **IEA** programs remained a central objective over the report period. The relevance of projects to photovoltaics, as well as better consistency, are both elements that will be given increased weight in future. Greater attention will also be paid to the new theme of international development cooperation.

2. Work completed and results for 2000

CELL TECHNOLOGY

At IMT, a new project phase commenced during the report period on **micromorphous solar cells** [1] that emphasises the industrially significant production stages and processes identified in a feasibility study on industrial implementation [36] in 1999. In this work, industrial practicability, and not so much the record values of single, isolated, parameters is decisive. The technique developed at IMT for thin film silicon continues to attract worldwide acknowledgment as a very promising option. Work is concentrating on improvement of the properties of transparent oxide films (TCO) based on ZnO, optimisation of the p-i-n and n-i-p film sequences using amorphous silicon, and manufacture of micromorphous minimodules. A TCO with good optical and electrical properties was deposited on surfaces of up 30 x 30 cm^2. It was demonstrated that when combined with good TCO and optimised cell design, a stabilised efficiency of 9% may be achieved even with simple p-i-n structures (amorphous Si). With the help of a new laser process, minimodules may now be structured more rapidly and interconnected monolithically, so that IMT now has access to all process steps necessary for industrial production. Micromorphous minimodules were fabricated with an active area of 23.3 cm^2 having a stabilised efficiency of 9.1%. The **SOLANT** [2] project supported by ESA was completed during the report period. In this, a new prototype satellite antenna with integral solar cell was constructed (0.9 W at 9.2 V under radiation conditions pertaining in space, active area 150 cm^2). Despite the low efficiency value, a performance of 433 W/kg was achieved on a polyimide substrate. Proton beam experiments demonstrated the different stability characteristics of amorphous and micromorphous solar cells.

CRPP at EPFL and IMT are cooperating with Unaxis (formerly Balzers) in a new KTI project on the **rapid large area deposition** [3] for thin film silicon solar cells. Drawing on the knowledge gained in earlier projects at IMT and CRPP, it is hoped to coat large substrates (of typically 1 m^2 and above) at frequencies of 27.12 and 40.68 MHz. During the report period, uniformity of the films and electrode design were the principal concerns.

A new KTI start-up project on the **continuous (roll-to-roll) fabrication process** [4] for producing amorphous solar cells on plastics substrates is being pursued at Le Locle College of Technology in collaboration with VHF Technologies. By *in situ* deposition of all required films on a 30 m long and 30 cm wide polyimide substrate, it is aimed to achieve a deposition capacity of 2,000 m^2/a at an efficiency of 3%. During the report period, the reactor (Fig. 1) was brought into operation, enabling the various films with the required properties to be deposited. The process will first be used for the manufacture of small electronics products.

Fig. 1: Roll-to-roll reactor at VHF Technologies
Photo: VHF Technologies

Over the report period, the development of **low bandgap cells** [5] was further pursued at PSI. These cells are intended for application to thermo-photovoltaics, requiring a suitable combination of radiation source, emitter, filter and photocell. The emission characteristics of spectrally selective emitters based on oxides of rare earths (Yb, Er) were measured. Selective filters are used to shield the photocell from longwave radiation, the radiation being reflected back to the emitter. A range of photocells (Si, Ge) were subjected both to AM 1.5 and to emitter radiation, and compared. The large differences found confirm the different spectral sensitivity of these cells.

Various EU projects concerning solar cells based on compound semiconductors were continued at the ETHZ in the thin film physics group. The **LACTEL** [6] project was completed during the report period. The structural and electronic properties of CdTe films in superstrate and substrate configurations were compared, whereby the substrate configuration proved to be more complex in respect of the rear contact. The **CADBACK** [7] project is concerned with optimisation of the rear contact. For CdTe cells, rear contacts based on Sb or Sb_2Te_3 and on Mo metal films produced efficiencies of 10 – 12% with acceptable stability. The **WIDE GAP CPV** [8] project was completed during the report period. In this, CIGS cells in superstrate configuration were deposited. These provided an efficiency of approx. 8% – only half the value for substrate configurations (15.8%) – this being explained by the low charge carrier concentration. The Na diffusion necessary to obtain acceptable film quality is hampered by the ZnO-Al film. In the **FLEXIS** [9] project, the CIGS cells are built up on flexible substrates. In 1999, a small-area flexible cell having an efficiency of 12.8% was deposited on polyimide. With this new approach, the polymer film is applied above the solar cell in the form of a window, enabling higher process temperatures to be used. The maximum efficiency achieved till now with this process is 8.5%, but it is expected that this can be considerably improved.

Dye-sensitised **nanocrystalline solar cells** (Grätzel cells) [10] continue to attract interest. At ICP at EPFL, work on fundamental aspects is being pursued, i.e. sensibilisation of the dye (spectral yield) and use of a solid-state heterojunction between the porous, dye-sensitised, surface and the solid electrolyte. The problem here is to establish intimate contact between these materials, thereby facilitating the necessary charge exchange. In a PSEL project, **outdoor measurements** [11] on dye-sensitised solar cells are in preparation to establish the behavior of these cells under realistic operating conditions. Of particular interest is their behavior under UV radiation. For this, the cells – or small modules – must be adequately packed. The **long-term stability** [12] of dye cells is the subject of an EU project at Solaronix. For this, an extensive measurement facility was set up during the report period, enabling the effects of UV-A radiation to be observed for different electrolyte compositions.

Fundamental work on **antenna solar cells** [13] has continued at the University of Bern as a part of its solar chemistry program, with the financial assistance of the Swiss National Science Foundation. The dye-injected zeolite crystals represent a form of dye-sensitised solar cell. The next step will be to attach the antennae to a suitable semiconductor.

The customary range of Swiss solar cell research was pursued over the report period with the support of many different institutions. Implementation to industrial products, both for small-scale applications and for processes, is taking on increasingly concrete form, and 'solar cells made in Switzerland' of the next generation are no longer a utopian fantasy. Prospects are good for the development of practical products in the coming years. At the same time, work on fundamental concepts for the next generation-but-one is continuing.

SOLAR MODULES AND BUILDING INTEGRATION (also see P+D)

In the EU **PV en face!** [14] project at the EPFL LESO laboratory, new designs for façade integrated solar cells are under development. New support systems oriented towards practical applications will be developed and tested. The prototypes will be built and tested in a step-by-step procedure. In the latest version, the demands made both on the mechanics and the aesthetics were convincingly satisfied. As practical outcome of this work, it is intended to commercialise a new product under the name of SOLFACE in spring 2001.

In the **DEMOSITE** [15] project, numerous variations on the theme of building integration of photovoltaics in flat roofs, gable roofs and façades may be seen in juxtaposition. The project forms part of the international IEA PVPS Task 7 program. The opportunities it offers for practical comparison have already enabled several products and systems to be conceived or improved in the course of projects. Three new stands were set up during the report period, namely SOLGREEN® (Fig. 2), COLT and PIL-SIM. The project may be visited virtually in Internet (www.demosite.ch), where detailed information may be obtained. It is also intended to provide a course of further education on the building integration of photovoltaics on the Internet. The final report summarises the work up to and including 1999 [37].

Fig. 2: Green roof photovoltaics installation with Solgreen at EPF Lausanne
Photo: LESO-EPFL

In the new EU **HIPERB** [16] project, Atlantis is developing a new variant of the SUNSLATES® product using CIGS cells. The project permits development of the conceptual advances needed for the application of thin film solar cells. This project is representative of a whole range of new systems for exploiting thin film solar cells for the building integration of photovoltaics that are expected to appear in the coming years.

Further new systems and products for the building integration of photovoltaics have been tested as part of P+D projects (see below).

SYSTEMS TECHNOLOGY

A new phase in the project on **quality assurance and energy yield of photovoltaics modules** [17] was begun at the LEEE TISO Institute of SUPSI during the report period. A new cycle of experiments was begun on 17 modules (7 sc-Si, 7 mc-Si, 2 a-Si and 1 CIS) using a new data acquisition system (Fig. 3). Initial results indicate heavy and continued negative deviations (>10%) from the specified output for some products. Detailed analyses were carried out for a range of radiation intensities and temperatures. During the report period, a Class A solar simulator was brought into operation. This will enable measurements under STC conditions to be carried out. The simulator facility is also available to third parties.

Preparations are in hand for certification of the laboratory. During the report period, long-term measurements on the three in-house installations were continued. In the new **MTBF-PV** [18] project, the long-term analyses carried out by TISO on the oldest grid-coupled photovoltaics installation in Europe (10 kWp, 1982) will be expanded in collaboration with the European test laboratory at Ispra. It was discovered that a large proportion of the modules displayed discoloration of the encapsulation compound and delamination. Nevertheless, both the modules and the installation gave good production performance. In order to obtain statistically relevant results it is intended to perform comprehensive measurements on all 273 modules.

Fig. 3: Test stand for module tests at LEEE TISO
Photo: NET Ldt.

Measurements [38] were also performed at PSI under **realistic operating conditions.** A comprehensive analysis enabled the energy yield characteristics of photovoltaics modules under part-load to be obtained. Modules based on new technologies were also tested.

The project on **quality assurance of photovoltaics installations** [19] was completed by the photovoltaics laboratory at Burgdorf College of Technology, where the emphasis lay on power inverters. To extend the range of test measurements, in addition to the existing 5 kW solar simulator a further simulator with a maximum output of 25 kW was built. This enables the larger inverters to be more quickly tested. Over the past 10 years, 27 grid-coupled inverters of between 100 W and 20 kW input were thoroughly tested. The results showed a significant reduction in the failure rate owing to the market experience gained and product improvements made during the period. Thanks to support from the Mont Soleil Association, the Burgdorf Electricity Company (now Localnet Ltd.), Elektra Baselland and SFOE, the **long-term observations** [20] on a wide range (i.e. 38) of photovoltaics installations could be continued. The installation on Mont Soleil has now been included in the measurement program of Burgdorf College of Technology. The EU **PV-EMI** [21] project was completed during the report period. Comprehensive measurements on induced voltages caused by lightning discharge for different module frames, aluminium backing foil and by-pass diodes were carried out. In addition, HF emission from the DC side was analysed, and new impedance values for grid simulation obtained.
In systems technology, the main emphasis lay on quality assurance of components (modules, power inverters), systems (design, energy yield) and installations (long-term observations). Particularly in the current phase of rapid market growth, the experience gained from these implementation-relevant questions is vital to ensure the safety and reliability of future installations and the standardisation of products.

OTHER PROJECTS AND STUDIES

The LESO laboratory at EPFL has completed preliminary work on the combined use of photovoltaics and thermal solar energy based on a **hybrid PV/T collector** [22]. The fundamental requirements on radiation absorption of amorphous silicon over the entire spectrum and its behavior at stagnation temperatures up to 210°C were established for a number of test samples and different material combinations. To achieve optimum solutions for combined application, it is apparent that further development work will be required, and that this must be closely oriented towards the market. Thermal performance is the main determinant of market potential for hybrid PV/T collectors.

The EU project on the **potential of photovoltaics on noise protection walls** [23] along roads and railroads in 6 European countries (CH, D, F, I, NL, UK) was completed by TNC. The theoretical potential is estimated in the study to be 83 GWp. The study shows a technical potential of 584 MWp along roads and 217 MWp along railroads. The generally accepted short-term potential in Germany, Holland and Switzerland is a total of 140 MWp for roads and 145 MWp for railroads.

In the EU **PVSAT** [24] project, Enecolo is working on remote monitoring of photovoltaics installations via satellite photography. During the report period, a database with 70 projects from Germany, Holland and Switzerland was prepared, and the yield of these installations monitored using the PVSAT software. It was shown that in most cases, forecasts of actual yield may be made with an accuracy of better than ±10%. In the new EU **ENERBUILD** [25] project, a network devoted exclusively to the theme of energy in buildings will be built up to record current European RTD activities and strengthen cooperation among the 57 partner institutions in this field. Information will be assembled on all relevant technologies, and applied to future priority areas and for market development. Enecolo is responsible for the *photovoltaics in buildings* basket.

In the EU **PHOTO-VENT** [26] project, Atlantis is working on an intelligent system for natural ventilation of buildings using photovoltaics.

A literature study on the **environmental aspects of photovoltaics** [27] was performed by ESU services to bring together the latest data on the subject. Based on this, the need for further action, particularly concerning energy and material flows in individual production processes, will be identified. As against the assessment carried out in 1996, non-renewable energy needs have declined significantly in the cases studied. Life cycle assessment in photovoltaics is also relevant to the theme of eco-labels for environmentally acceptable electricity production.

In the EU **multi-user solar hybrid grids** [28] project, the University of Zurich is studying the social scientific aspects of solar electricity generation in villages remote from the grid. The work will focus on the effects this has on social organisation in the communities concerned.

INTERNATIONAL COOPERATION WITHIN IEA, IEC and PV GAP

Over the report period, participation in the IEA PVPS photovoltaics program was characterised by continuity both at project level and regarding membership of the Executive Committee. Reports and publications on the program may be viewed via the corresponding website (www.iea-pvps.org).

On Task 1, concerned with general **information work** [29], Switzerland is represented by NOVA Energy. A further national report on the photovoltaics scene in Switzerland up to 1999 [80] was prepared during the report period. This formed the basis of the 5th edition of the annual international report on market developments in photovoltaics in IEA countries [81]. The IEA PVPS Newsletter [82] provides information on the work of the IEA program and associated themes at regular intervals. On the occasion of the 16th European PV Conference in Glasgow, a further workshop was organised on the subject of value analysis in photovoltaics.

TNC is the Swiss expert in the Task 2 project on **operational experience** [30]. The international database was completely revised during the report period and extended to new installations. In future, installations for which longer term operating experience is available will be singled out as case studies for analysis. The results of the analyses made up to 1999 were presented in a comprehensive final report [37].

Dynatex is participating in the work on **island installations** [31] in Task 3. The main concerns of this project are improvements in the quality and reliability of autonomous photovoltaics installations, and technical questions on hybrid systems and batteries [83, 84]. A workshop on questions of quality assurance was organised in Switzerland during the report period.

EWZ is responsible for the Swiss contribution to Task 5 concerning technical questions on **grid coupling** [32] of photovoltaics installations. The review of national regulations on grid coupling was revised during the report period. Island operation of photovoltaics installations is the subject of further comprehensive investigations. The characteristics of electrical networks to which a large number of photovoltaics installations are connected will be simulated with the aid of computer programs.

Task 7 on the theme of **integration of photovoltaics in the built environment** [33] is being managed by Enecolo. A database with 450 building integrated projects can be accessed under www.task7.org. Further contributions seen from a design viewpoint center on case studies, examples and tools. Switzerland's contribution consisted of the PVSYST 3.0 software [75]. Switzerland is also coordinating the Subtask concerned with technical aspects. Non-technical aspects are also being studied, and an initial report was published [85]. On behalf of Switzerland, NET is submitting a contribution on questions of potential. Wide-ranging information activities took place during the report period, examples being the Solar Electric Buildings Conference, a design competition and – from Switzerland – the DEMOSITE project at EPLF (see above). Several Swiss projects received awards in the design competition.

With the support of the State Secretariat for Economic Affairs (seco), Entec is responsible for the Swiss contribution to Task 9 on **photovoltaics development cooperation** [34]. The efforts to formulate recommendations concerning application of photovoltaics in developing countries have reached a concrete stage and preliminary drafts were prepared. In this project, Switzerland is responsible for coordinating the work with bilateral and multilateral organisations. At the national level, efforts are underway to strengthen Swiss photovoltaics in this important area.

Alpha Real is representing Switzerland in TC 82 of IEC and is leading the working group to prepare and issue suggestions for international standards for photovoltaics systems [74]. Alpha Real is also participating in the work on **PV GAP (PV Global Approval Program)** [35], a worldwide program on quality assurance and certification for photovoltaics systems. Over the report period, progress was made in terms of growing acceptance of PV GAP in industry and the financial world, and of simplified procedures for awarding PV GAP eco-labels (i.e. marks and seals). A first series of products was successfully certified.

3. National cooperation

The diversity of national cooperation in projects and professional events was upheld over the report period. New projects were started in cooperation with industry. The workshops on specific themes and the national Photovoltaics Conference in Neuchâtel are also mentioned. This highly appreciated event provides an opportunity for an intensive exchange of experience and detailed discussion, where new ideas and approaches can be discussed. An strong interaction also takes place here between research and development, professional circles, the electricity industry and the authorities.

Cooperation was also expanded at program level with numerous federal agencies, the cantons and the electricity industry. In this, the constant exchange with BBW, KTI, SAEFL, SDC and seco, and also with VSE, PSEL and the Mont Soleil Association, are particularly mentioned. All in all, these efforts helped to provide a broader base for project activities in the photovoltaics program.

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 the project level, cooperation continued within the EU during 2000, this concerning 15 projects in research and 4 projects in the EU energy program. Further projects in the Altener programs and with ESA are in progress. Ratification of the bilateral agreements should improve the standing of the Swiss partners in EU projects. Regular contacts were maintained with responsible quarters in Brussels. Concerning development cooperation, new contacts were established with international organisations (World Bank, GEF, IFC, UNDP, GTZ, KfW etc.). On the whole, it can be said that Switzerland is well placed in the international photovoltaics field.

5. P+D projects

SHORT SUMMARY

During 2000, a total of 43 photovoltaics P+D projects were in progress. In addition, 10 projects in the PV P+D program of the SFOE were under scrutiny at the beginning of 2001. The P+D activities concerned pilot plants, component development, measurement campaigns, studies and tools. The field was led by full-scale pilot projects for testing new components in P+D installations. More than half the projects centered on the theme of **building integration of photovoltaics.** The remaining projects concerned inverter technology, noise protection, stand-alone installations, measurements on various different installations, quality assurance and PV planning tools.

The generally high quality level of Swiss P+D projects is illustrated by the growing market success of their products in Switzerland and abroad. Swiss P+D projects regularly achieve international acknowledgement – a clear mark of quality. The following examples are cited:

- SOLRIF **SOL**ar **R**oof **I**ntegration **F**rame [41] (Fig. 4)
- LonWorks as field bus for PV installations [44] (Fig. 5)
- Solar sail in Münsingen [62]

Fig. 4: Roof integration with SOLRIF
Photo: Enecolo Ltd.

Fig. 5: Inverter prototype with LON nodes
Photo: NET Ltd.

P+D PROJECTS IN 2000

New P+D projects

In 2000, 10 new projects were begun in the PV P+D program. The emphasis remained on the installations sector, where half the projects were situated. In the building integration sector, the thermally insulated jointed metal roof comprising amorphous triple cells [55] (Fig. 6) is certainly of particular interest. The experience gained was directly exploited in further developing the system. First-time application to an installation of the latest generation is planned for spring/summer 2001. Following the positive results obtained in the laboratory and from tests on 3 power inverters based on LonWorks as communication platform [44] (Phase 1, Fig. 5), a 250 kWp pilot project involving 68 power inverters of this type was commissioned in February 2001 (Phase 2). It is interesting to note that power inverters on LON communication platforms were explicitly mentioned as one of the highlights of the exhibition in the final summary of the 15th PV Symposium 2000 in Staffelstein. In summer 2001, test runs will begin on a passenger ferry carrying 200 persons (Fig. 7), whose motive power will come from a 20 kWp photovoltaics installation on the cabin roof (autonomous installation) [66].

Fig. 6: Thermally insulated PV jointed metal roof
Photo: NET Ltd.

Fig. 7: Illustration of the solar ferry
(© Dransfeld, dyne design engineering gmbh)

The projects begun in 2000 were as follows:

Installations

- 3 kWp PV Eurodach amorph (thermally insulated PV jointed metal roof with amorphous triple cells, building integration. Management: PAMAG Engineering), Fig. 6 [55]
- 80 kWp PV noise installation plant A1 in Safenwil (combined photovoltaics-wood noise barrier in modular construction and partially prefabricated elements. Management: Ekotech Ltd.) [59]
- 10 small-scale roof integrated PV systems (small-scale integrated PV installation (240 Wp), mostly combined with thermal installation, building integration. Management: Ernst Schweizer Metallbau Ltd.) [56]
- PV assisted, electric powered, passenger ferry (catamaran with passenger capacity of 200, and autonomous 20 kWp installation providing power for the electrical drive motor. Management: Minder Energy Consulting), Fig. 7 [66]
- 250 kWp PV installation equipped with LonWorks (Phase 2) field bus power inverters (pilot plant with 68 PV power inverters with LON nodes for data exchange and monitoring of the plant. Management: Sputnik Engineering Ltd.) [44]

Component development

- Solgreen system optimisation (system optimisation with respect to costs, ease of fitting, material, building integration. Management: Enecolo Ltd.) [46]
- Sunplicity solar roof slates (development of a PV roof slate, particular attention being paid to high structural stability, aging resistance, simple installation and cabling, building integration (Management: Alpha Real Ltd.) [47]

Studies – tools – various projects

- HORIZsolar Phase II (precise digital acquisition and processing of the horizon for solar energy installations, implementation, PV tools. Management: Energiebüro) [77]
- Feasibility study for photovoltaics installation Wankdorf stadium (establishment of engineering fundamentals for realisation of a large-scale PV installation with thin film technology, study. Management: Ingenieurbüro Hostettler) [78]
- PV City Guide (examples of PV installations in urban areas. Management: Swiss contribution: NET Ltd.) [79]

Current P+D projects

Among the current P+D projects for installations, those with transparent modules (partly with insulating glass) are of particular interest from an architectural point of view (Stadelhofen Cantonal School [64] (Fig. 8), PV roofs in the old town of Unterseen [53] (Fig. 9), shed roof integration in Domdidier [48]). By substituting conventional insulation glass (with or without combined shading system) with photovoltaics insulating glass, and exploiting existing support structures, there is considerable potential for cost reductions. This is shown by recent installations of this type that did not have P+D support. As far as the support structures are concerned, there is a general demand for inexpensive products. Further cost reductions should be possible through even simpler mounting of the modules than at present, as illustrated by the 30 kWp shed roof in Hünenberg [54].

In other sectors, a useful yield increase has been achieved for modules with specially coated glasses [73], and improved quality assurance measures [76] have been implemented.

Fig. 8: Insulating glass modules at Stadelhofen Cantonal School, Photo: NET Ltd.

Fig. 9: PV roofs in the old town of Unterseen Photo: NET Ltd.

Current projects include:

Installations

- Hybrid 7 kWp PV installation Domdidier, (hybrid electricity - hot air plant, building integration. Management: GEIMESA) [48]
- 6.4 kWp installation integrated in the roof of the Institute of Microtechnology in Neuchâtel (PV elements with amorphous cells, building integration. Management: IMT) [49]
- Three 10 kWp photovoltaics noise barrier installations along the expressway (photovoltaics - noise protection combination, 3 prototype plants. Management: TNC Consulting) [58]
- Héliotrope, 3 x 2 kWp PV installations in Le Locle (direct comparison of identical, but differently installed systems (building integration, stand-alone, tracking). Management: EICN, Le Locle) [61]
- 10 kWp "SolGreen" installation integrated in a grass roof (newly developed support structure for grass roofs, flat-roof integration. Management: ars solaris hächler) [57]
- 3 kWp roof integration with Sunslates (autonomous plant, building integration. Management: Atlantis Solar Systems Ltd.) [51]
- Héliotram, 800 kWp PV installations Lausanne/Geneva with DC direct injection into the tram grid (Management: Sunwatt Bio Energie Ltd.) [68]
- 151 small grid-coupled PV installations (small-scale installations with phase power inverters, total capacity 200 kWp, including 30 kWp in Switzerland. Management of Swiss contribution: Phebus Suisse) [67]
- 3 kWp installation at Amburnex Farm (mobile island installation with auxiliary diesel generator supplying electric power to an alp, autonomous installation. Management: Services Industriels Lausanne) [63]
- 23.5 kWp PV installations Cantonal School Stadelhofen (PV insulating glass and shading system, building integration. Management: TNC Consulting) [64], Fig. 8
- 6 kWp PV roofs the old town of Unterseen (PV integration in historic buildings, building integration. Management: Industrielle Betriebe Interlaken) [53], Fig. 9
- PV installation at Wauwilermoos penitentiary (PV demonstration installation. Management: Kantonale Fachstelle für Energiefragen, Lucerne) [65]
- 31 kWp installation EG Hünenberg (PV installation with new, inexpensive, support structure for standard modules. Management: Urs Bühler Energy and Engineering) [54]

Component development

- SOLight module support structure (lightweight support structure for flat-roof installations. Management: Energiebüro) [43]

Measurement campaigns

- Visualisation and evaluation of PV installation on the Rothorn (Management: Chur Technical College) [69]
- 1 Megawatt solar chain of NOK (normalised data 1997-2001. Management: Axpo) [70]
- Measurement campaign Mark I (100 kWp installation A 13. Management: TNC Consulting Ltd.) [72]
- 47.5 kWp installation IBM (self-cleaning surface coating of modules, flat-roof installation. Management: Amstein & Walthert, Zürich) [73]

Studies – tools – various projects

- Standardisation work on PV systems (Management: Alpha Real) [74]
- GRS guaranteed results for PV systems (EU Altener project, quality assurance. Management Swiss contribution: Energiebüro) [76]
- PV on vocational Colleges in Switzerland (Management: TNC Consulting) [A]
- Photovoltaic Energy Statistics of Switzerland 1999 (Management: Energiebüro) [B]
- Solar electricity from the utility (Management: Linder Kommunikation) [C]

Projects completed in 2000

Among the projects completed this year, the solar sail project in Münsingen [62] was very prominent, attracting the attention of the media, and reflecting the successful efforts of the project workers in this area. Another highlight was the newly developed SOLRIF roof integration frame (Fig. 4) for standard modules [41], which was implemented in Switzerland and abroad in roof integrated installations in the course of 2000, with a total capacity of approx. 250 kWp. Work on revising the PVSYST 3.0 PV software [75] was also completed. This design and simulation program was acclaimed in Photon 1-2000 as one of the most powerful programs of its kind. Over half the P+D projects completed in 2000 are just entering, or have yet to enter, the market introduction phase. The coming years will show which of the prototypes can advance to become marketable products and establish themselves in the market.

The following projects covering all P+D areas can be listed as completed:

Installations

- 4.8 kWp installation with SOLRIF modules (newly developed module frame for roof integration of standard modules, building integration. Management: Enecolo Ltd.) [52]
- 8 kWp solar sail in Münsingen (PV installation with arresting appearance, demonstration plant. Management: Verein Sonnensegel Münsingen) [62]
- 16.3 kWp installation with PV AC modules integrated in the roof of a farm house in Iffwil (PV elements with integrated inverters, hybrid installation electricity / hot air, building integration. Management: Atlantis Energie) [50]
- AC noise protection installation Amsterdam (combined AC module and noise protection. Management: Swiss contribution: TNC Consulting) [60]

Component development

- LonWorks as field bus for PV installations Phase 1 (development of a power inverter with LonWorks inverter nodes, standardised data transfer for PV installations. Management: Sputnik Engineering Ltd.) [44], Fig. 5
- SOLRIF: frame for standard modules for roof integration (building integration. Management: Enecolo) [41], Fig. 4
- SOLMAX (shell shaped support structure in recycled plastic for large PV modules, flat roof installation. Management: Solstis Sàrl) [45]
- Photovoltaics outdoor insulation elements for roof and façade (building integration. Management: ZAGSOLAR) [42]
- 2 kWp installation with power inverter modules (installation with newly developed alternating current PV modules. Management: Biel Technical College) [40]

Measurement campaigns

- 180 kWp installations at UBS Suglio (comparison of various installation layouts. Management: Enecolo Ltd.) [71]

Studies – tools – various projects

- HORIZsolar Phase I (exact digital measurement and processing of the horizon for solar energy installations, PV tools. Management: Energiebüro) [77]
- PVSYST V3; ergonomie et fonctionnalité (successor to PVSYST 2.0. Management: EPFL) [75]

6. Implementation

The process of practical implementation continued during the report period. Of particular interest are new implementation projects for thin film solar cells and dye cells. For these, cooperation was established with existing and newly founded companies, thereby taking a further step in the direction of the final 'solar cells made in Switzerland' objective. A number of other industrial companies are also preparing concrete steps in this direction.

In addition to the cell-oriented projects already mentioned, implementation is continuing in the field of components for building integration. Advanced and increasingly reliable power inverters are becoming available at ever lower prices, demonstrating that implementation in this area is already well advanced. In total, important contributions to implementation could be made thanks to broad program support, and above all to the new KTI projects and trials in P+D projects.

By the end of 2000, it is anticipated that in Switzerland photovoltaics installations with a capacity of some 15 MWp will be in operation, and of these, about 3/4 will be grid coupled. The proportion of island installations is around 1/4 of installed capacity, comprising an estimated 30,000 small-scale island installations. Although the total capacity of 15 MWp lies far below the 50 MWp target set by Energy 2000, it nevertheless figures among the highest *per capita* installed capacities worldwide. Moreover, the trend towards cost reductions continues.

7. Assessment for 2000 / perspectives for 2001

The plebiscite of 24 September 2000 undoubtedly made its mark on the year 2000, with its high hopes prior to, and corresponding disappointment after, the negative outcome. Fortunately, this had no direct bearing on the research, development and demonstration projects discussed in the present report, there being no doubt on any side concerning the necessity for sustained research and development. It should therefore prove possible to mobilise finance of the same order as hitherto. In view of the continuing tight financial situation, broad program support remains essential.

From a technological standpoint, and as far as implementation is concerned, the year 2000 must be rated a success. This is shown by the examples cited. The discussions and reports in the media in connection with the plebiscite, and also the growing awareness of the expanding world-wide photovoltaics market, have triggered greater attention in many circles. Committed interest was noticeable on the part of industry and finance. This conclusion maintains its validity regardless of the result of the plebiscite of 24 September, which only goes to underline the international dimension of photovoltaics, not least in Switzerland.

Swiss photovoltaics were widely present at the 16th European Photovoltaics Conference in Glasgow [86]. The National Photovoltaics Conference, which took place during the report period in Neuchâtel [87], illustrated the many aspects involved in photovoltaics from the Swiss perspective. The meeting is generally regarded as a very worthwhile event.

It may be concluded from the above observations that there will be no standstill in Swiss photovoltaics in 2001. Exciting developments are expected in the industrial sector, international orientation will be more pronounced, and – thanks to further expansion of the solar exchanges – market volume will remain at about the same level. Although developments may not prove as rapid as originally hoped, they will undoubtedly take place in the right direction. Information exchange will be expanded by means of workshops centering on specific themes. Last but not least, to satisfy the increasing demand for information, a comprehensive website www.photovoltaic.ch will be made available in Internet.

8. List of Research projects and Internet websites

[1] A. Shah, IMT, UNI - Neuchâtel: **Micromorphous solar cells project.** (AR) / http://www-micromorph.unine.ch

[2] A. Shah, IMT, UNI - Neuchâtel: **Integration of Antennas with Solar Cells (SOLANT) Advanced Solar Antennas (ASOLANT).** (AR) / http://www-micromorph.unine.ch

[3] Ch. Hollenstein, CRPP / EPF - Lausanne: **Large area and high-throughput coating system (PECVD) for silicon thin-film solar cells.** (AR) http://www.epfl.ch

[4] G. Frosio, H. Keppner, EICN - Le Locle / D. Fischer, P. Torres, A. Closset, VHF-Technologies - Le Locle: **Industrial fabrication process for the manufacturing of flexible solar cells on thin plastic film designed to supply autonomous electronic devices.** (AR) / http://www.vhf-technologies.com

[5] J. Gobrecht, PSI - Villigen: **Development of low bandgap cells.** (AR) / http://www.psi.ch/LMN

[6] H. Zogg, A. N. Tiwari, IQE / ETH - Zürich: **Large Area Cadmium Telluride Electro deposition For Thin Film Solar Cells (LACTEL).** (AR) / http://www.tfp.ethz.ch

[7] A. N. Tiwari, H. Zogg, IQE / ETH - Zürich: **The CdTe thin film solar cell-improved back contact (CADBACK).** (AR) / http://www.tfp.ethz.ch

[8] H. Zogg, A. N. Tiwari, IQE / ETH - Zürich**: Wide gab chalcopyrites for advanced photo voltaic devices (WIDE GAP CPV).** (AR) / http://www.tfp.ethz.ch

[9] A. N. Tiwari, H. Zogg, IQE / ETH - Zürich: **CIS thin film solar cells on flexible substrates (FLEXIS).** (AR) / http://www.tfp.ethz.ch

[10] M. Grätzel, ICP2 / EPF - Lausanne: **Dye sensitised nanocrystalline solar cells.** (AR) / http://dcwww.epfl.ch/icp/ICP-2/icp-2.html

[11] M. Grätzel, ICP2 / EPF - Lausanne: **Outdoor measurements on dye-sensitised solar cells.** (AR) / http://dcwww.epfl.ch/icp/ICP-2/icp-2.html

[12] A. Meyer, Solaronix Ltd., Aubonne **Long Term Stability of Dye Solar Cells for Large Area Power Applications LOTS-DSC.** (AR) / http://www.solaronix.ch

[13] G. Calzaferri, Departement für Chemie und Biochemie, UNI - Bern: **Antenna solar cells.** (AR) / http://iacrs1.unibe.ch

[14] Ch. Roecker, LESO / EPF - Lausanne: **PV en face!** (AR) / http://lesomail.epfl.ch/

[15] Ch. Roecker, LESO / EPF - Lausanne: **Demosite and Demosite Flat Roofs (part IV).** (AR) / http://www.demosite.ch/page/index.html

[16] R. Neukomm, Atlantis Solar Systeme Ltd., Bern: **HIPERPB: High Performance Photo voltaics in Buildings.** (AR) / http://www.atlantisenergy.ch

[17] G. Travaglini, LEEE, SUPSI - DCT, Canobbio: **Quality assurance and energy yield of photovoltaics modules TISO - period VI: 2000-2002.** (AR) / http://www.leee.dct.supsi.ch

[18] G. Travaglini, SUPSI - Canobbio: **Mean Time Before Failure of Photovoltaic modules (MTBF-PVm).** (AR) / http://www.leee.dct.supsi.ch

[19] H. Häberlin, HTA - Burgdorf: **Quality assurance of photovoltaics installations.** (AR, FR) / http://www.hta-bu.bfh.ch /e/pv/pv-indd.htm

[20] H. Häberlin, HTA - Burgdorf: **Long-term observations on a wide range of photovoltaics installations 2.** (AR) / http://www.hta-bu.bfh.ch /e/pv/pv-inde.htm

[21] H. Häberlin, HTA - Burgdorf: **PV - EMI : Development of standard test procedures for electro-magnetic interference (EMI) tests and evaluations on photovoltaic components and plants.** (AR) / http://www.hta-bu.bfh.ch /e/pv/pv-inde.htm

[22] Ch. Roecker, LESO / EPF - Lausanne: **New Generation of Hybrid Solar PV/T Collectors.** (AR) / http://lesomail.epfl.ch/

[23] Th. Nordmann, TNC Consulting, Erlenbach: **EU PVNB POT: Evaluation of the potential of pv noise barrier technology for the electric production and market share.** (AR) **/** http://www.tnc.ch

[24] P. Toggweiler, Enecolo Ltd., Mönchaltorf: **PVSAT: Remote performance check for grid connected PV systems using satellite data.** (AR) / http://www.solarstrom.ch

[25] P. Toggweiler, Enecolo Ltd., Mönchaltorf: **Thematic Network: Energy in the Built Environment (EnerBuild).** (AR) / http://www.solarstrom.ch

[26] A. Eckmanns, Atlantis Solar Systeme Ltd., Bern: **PHOTO-VENT: Development of PV-powered smart natural ventilation devices.** (AR) / http://www.atlantisenergy.ch

[27] R. Frischknecht, N. Jungbluth, ESU-Services, Uster: **Literature study on the environmental aspects of photovoltaics.** (FR) / http://www.esu-services.ch

[28] H. -J. Mosler, UNI - Zürich: **Combined Project on Multi-User Solar Hybrid Grids.** (AR) / http://www.psych.unizh.ch/sozpsy

[29] P. Hüsser, Nova Energie GmbH, Aarau: **SWISS Contribution to the IEA Implementing Agreement on Photovoltaic Power Systems (PVPS), TASK 1.** (AR)/ http://www.novaenergie.ch

[30] A. Frölich, L. Clavadetscher, Th. Nordmann, TNC Consulting Ltd., Erlenbach: **IEA: Photo voltaic Power Systems (PVPS), TASK II.** (AR) / http://www.tnc.ch

[31] M. Villoz, Dynatex Ltd., Morges: **IEA PVPS Task III: Use of photovoltaic systems in stand-alone and island applications.** (AR) / http://www.task3.pvps.iea.org/

[32] S. Taiana, EWZ - Zürich: **IEA PVPS TASK V: Grid Interconnection of Building- Integrated and other dispersed Photovoltaic Power Systems.** (AR) / http://www.ewz.ch

[33] P. Toggweiler, Enecolo Ltd., Mönchaltorf: **IEA PVPS TASK VII: Photovoltaic Power Systems in the Built Environment.** (AR) / http://www.solarstrom.ch

[34] S. Nowak, NET Ltd., St. Ursen: **Swiss Contribution to the IEA PVPS Task IX.** (AR)

[35] M. Real, Alpha Real Ltd., Zürich: **Global Approval Programm - PV GAP.** (AR) / http://www.pvgap.org

[36] A. Shah, IMT, UNI - Neuchâtel: **Feasibility Study Micromorph Solar Cell.** (FR) / http://www-micromorph.unine.ch

[37] Ch. Roecker, LESO / EPF - Lausanne: **Demosite and Demosite Flat Roofs- Phase III.** (FR) / http://lesomail.epfl.ch/

[38] W. Durisch, PSI, Villigen: **Characterisation of Photovoltaic Generators.** / http://www.psi.ch/

(AR) Annual report 2000 available

(FR) Final report available

9. List of P+D projects and Internet websites

[40] V. Crastan, HTA Biel: **Pilot plant 2 kWp for modul integrated inverters.** (AR, FR)

[41] P. Toggweiler, Enecolo Ltd., Mönchaltorf: **SOLRIF (Solar Roof Integration Frame).** (AR, FR) / http://www.solarstrom.ch

[42] R. Durot, Zagsolar, Kriens: **PV-insulation-modules.** (AR, FR)

[43] Ch. Meier, Energiebüro, Zürich: **New Light-Weight Flat Roof Photovoltaic Module. Mounting System.** (AR, FR) / http://www.energieburo.ch

[44] Ch. von Bergen, Sputnik Engineering Ltd., Nidau: **LonWorks as Fieldbus for PV-Installations.** (AR, Zwischenbericht) / http://www.solarmax.com

[45] J. Bonvin, Solstis Sàrl, Lausanne: **SOLMAX, flat roof mounting system made of recycling material.** (AR, FR) / http://www.solstis.ch

[46] P. Toggweiler, Enecolo Ltd., Mönchaltorf, **SOLGREEN- Solgreen system optimisation.** (AR) / http://www.solarstrom.ch

[47] M. Real, Alpha Real Ltd., Zürich: **Sunplicity solar roof slates.** (AR)

[48] J. Audergon, GEIMESA, Fribourg: **Hybrid 7 kWp PV installation, Domdidier.** (AR) / http://www.geimesa.ch

[49] R. Tscharner, IMT, Université de Neuchâtel: **Roof integrated amorphous silicon photovoltaic plant IMT Neuchâtel.** (AR) / http://www-micromorph.unine.ch

[50] B. Stucki, Atlantis Energie Ltd., Bern: **PV-roof integration with module integrated inverters.** (AR, FR) / http://atlantisenergy.ch

[51] B. Bezençon, Atlantis Solar Systeme Ltd., Bern: **3,1 kW_p stand-alone hybrid (PV-Diesel) installation in Soyhières (JU).** (AR) / http://www.atlantisenergy.com

[52] P. Toggweiler, Enecolo Ltd.; Mönchaltorf: **4.8 kWp P+D PV plant SOLRIF, Lindenmatt.** (AR, FR) / http://www.solarstrom.ch

[53] F. Bigler, Industrielle Betriebe Interlaken: **PV roofs in the old town of Unterseen.** (AR) / http://www.ibi-interlaken.ch

[54] U. Bühler, Urs Bühler Energy Systems and Engineering, Cham: **Slopedroof- and façade – mounting-system AluTec / AluVer.** (AR)

[55] H. Kessler, PAMAG Ltd., Flums: **3 kWp PV Eurodach amorph.** (AR) / http://www.flumroc.ch

[56] A. Haller; Ernst Schweizer Ltd., Hedingen: **10 Roof Integrated PV Small Scale Systems.** (AR) / http://www.schweizer-metallbau.ch

[57] R. Hächler, Ars Solaris Hächler, Chur: **Pilot installation 10kWp Flat Roof System "SOLGREEN".** (AR)

[58] Th. Nordmann, TNC Consulting, Erlenbach: **Three pilot 10 kWp integrated PV sound barrier fields.** (AR) / http://www.tnc.ch

[59] R. Hottiger, IG Solar Safenwil**: PV / Noise Barrier Installation "Alpha A1" in Safenwil.** (AR) / http://www.ekotech.ch

[60] Th. Nordmann, TNC Consulting Ltd., Erlenbach: **Large scale integration of AC PV modules into a noise barrier along a highway near Amsterdam.** (AR) / http://www.tnc.ch

[61] G. Jean-Richard, EICN, Le Locle: **PV Anlage Héliotrope EICN.** (AR) / http://www.eicn.ch

[62] S. Kormann, Verein Sonnensegel, Münsingen: **SOLARSAIL Münsingen.** (AR, FR) / http://www.solarsail.ch

[63] P. Favre, Services Industriels Lausanne: **Amburnex Solar Farm. (3 kWp).** (AR) / http://www.lausanne.ch/energie

[64] Th. Nordmann, TNC Consulting, Erlenbach: **27 kWp PV-Installation High School Zurich-Stadelhofen.** (AR) / http://www.tnc.ch

[65] R. Durot, ZAGSOLAR; Kriens: **PV-installation Wauwilermoos.** (AR, FR)

[66] R. Minder, Minder Energy Consulting, Oberlunkhofen: **SolarCat - Solar-Electric powered Passenger Ship.** (AR) / http://www.minder-energy.ch

[67] R. Diamond, Phébus Suisse, Genève **151 small grid connected PV stations for a total of 200 kWp, of which 30 kWp in Switzerland.** (AR) / http://www.ecotourisme.ch.

[68] M. Schneider, Sunwatt Bio Energie Ltd., Chêne Bourg: **HELIOTRAM : 800 kWp PV power plants for direct injection in light train low voltage D.C. networks.** (AR) / http://www.sunwatt.ch

[69] M. Schalcher, Ingenieurschule HTA, Chur: **Visualisation and Analysis of the Data of the 4,1kWp PV-Power Plant Rothorn.** (AR) / http://www.fh-htachur.ch

[70] S. Roth, Axpo, Zürich: **NOK's 1-Megawatt Solar Chain, Normalised Data 1997 to 2001.** (AR) / http://www.axpo.ch

[71] R. Kröni,: Enecolo Ltd., Mönchaltorf: **Monitoring of the 180 kWp PV-Power Plant of UBS Suglio/Lugano.** (AR, FR) / http://www.solarstrom.ch

[72] Th. Nordmann, TNC Consulting, Erlenbach: **Measurement campaign Mark I.** (AR) / http://www.tnc.ch

[73] A. Schlegel, awtec Ltd., Zürich: **Coating of PV-Modules.** (AR) / http://www.awtec.ch

[74] M. Real, Alpha Real, Zürich, **Standardisation work on PV systems.** (AR) / http://www.iec.ch

[75] Ch. Roecker, LESO - EPF Lausanne: **PVSYST 3.0.** (AR, FR) / http://www.pvsyst.com/

[76] Ch. Meier, Energiebüro, Zürich**: Guarantee of Solar Results for Grid-Connected-Photovoltaic-Systems 'GRS-PV'.** (AR, FR) / http://www.energieburo.ch

[77] Ch. Meier, Energiebüro, Zürich: **HORIZsolar.** (AR; FR) / http://www.energieburo.ch

[78] Th. Hostettler, Ingenieurbüro Hostettler, Bern: **Feasibility Study "PV installations with Thin-film Cells integrated into football stadiums".** (AR)

[79] S. Nowak, NET Ltd., St. Ursen, **PV City Guide.** (AR) / http://pvcityguide.energyprojects.net

[A] Th. Nordmann, TNC Consulting, Erlenbach: **PV on vocational Colleges in Switzerland, 7 Years Experience in Training and Education.** (AR) / http://www.pv-berufsschule.ch

[B] Ch. Meier, Energiebüro, Zürich, **Photovoltaic Energy Statistics of Switzerland 1999.** (AR) / http://www.energieburo.ch

[C] E. Linder, Linder Kommunikation Ltd. G, Zürich, **Solar electricity from the utility.** (AR) / http://www.linder-kom.ch **/** http://www.strom.ch/deutsch/ch-strom/solarstrom-ew.asp

(AR) Annual report 2000 available
(FR) Final report available

10. References

[80] Swiss national report on PV power applications 1999, P. Hüsser, Nova Energie, 2000

[81] Trends in Photovoltaic Applications in selected IEA countries between 1992 and 1999, IEA PVPS Task I – 08: 2000

[82] IEA PVPS Newsletter, distributed by Nova Energie, Schachenallee 29, 5000 Aarau, Fax 062 834 03 23

[83] Lead-Acid Battery Guide for Stand-Alone Photovoltaic Systems, IEA Task III, Report IEA-PVPS 3 - 06: 1999

[84] Survey of National and International Standards, Guidelines & QA Procedures for Stand-alone PV Systems, IEA PVPS T3 - 07: 2000

[85] Literature survey and analysis of non-technical problems for the introduction of building integrated photovoltaic systems, IEA PVPS Task7-01: 1999

[86] 16th European Photovoltaic Solar Energy Conference and Exhibition in Glasgow – aus Schweizer Sicht, BFE, 2000

[87] Nationale PV-Tagung 2000, documents available at VSE, Gerbergasse 5, 8023 Zürich, Fax 01 221 04 42

11. Further information

Further information is obtainable from the program management:

Dr. Stefan Nowak, NET Nowak Energie & Technologie Ltd.,
Waldweg 8, 1717 St. Ursen, Switzerland
Phone. ++41 26 494 00 30, Fax. ++41 26 494 00 34, Email: stefan.nowak.net@bluewin.ch

Edited by: Stephan Gnos, Manuela Schmied,
NET Nowak Energie & Technologie Ltd., mail.net@bluewin.ch

Translation: en-solar, Mr. P. Case
Hubel / Wangelen 153A, 3615 Heimenschwand, Switzerland

12. Abbreviations (and Internet websites)

General terms

HES	Haute Ecole Spécialisée	
HTA	Institute of Engineering and Architecture (University of Applied Sciences)	

Funding institutions

FOGA	Forschungs-, Entwicklungs- und Förderfonds der schweizerischen Gasindustrie	
PSEL	Fund for Projects and Studies of the Swiss Electric Utilities	http://www.psel.ch

National institutions

ATAL	Amt für technische Anlagen und Lufthygiene des Kantons Zürich	
BBW	Federal Office for Education and Science	http://www.admin.ch/bbw
CRPP	The Plasma Physics Research Centre of Switzerland EPFL	http://crppwww.epfl.ch
EAWAG	Swiss Federal Institute for Environmental Science and Technologie	http://www.eawag.ch
EICN	Ecole d'Ingénieurs du Canton de Neuchâtel	http://www.eicn.ch
EMPA	Swiss Federal Laboratories for Materials Testing and Research	http://www.empa.ch
EPFL	Ecole Polytechnique Fédérale 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
HTA Burgdorf	University of Applied Sciences Burgdorf	http://www.hta-bu.bfh.ch
HTA Chur	University of Applied Sciences Chur	http://www.fh-htachur.ch
ICP	Institut de Chimie Physique EPFL	http://dcwww.epfl.ch/icp/ICP-2/icp-2.html
IMT	Institut de Microtechnique Universität Neuchâtel	http://www-imt.unine.ch
IQE	Institute of Quantum Electronics ETHZ	http://www.iqe.ethz.ch
KTI	Kommission für Technik und Innovation	http://www.admin.ch/bbt/d/index.htm
LEEE - TISO	Laboratory of Energy, Ecology and Economy - Ticiono	http://leee.dct.supsi.ch
LESO	Laboratoire d'Energie Solaire EPFL	http://www.lesomail.epfl.com
OPET	Federal Office for Professional Education and Technology	http://www.admin.ch/bbt
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 coorperation	http://www.admin.ch/deza
SECO	State Secretariat for Economic Affairs	http://www.seco-admin.ch
SFOE	Swiss Federal Office of Energy	http://www.admin.ch/bfe
SI Lausanne	Services Industriels Lausanne	http://www.lausanne.ch/energie/epsilon/default.htm
SUPSI	Scuola universitaria professionale della Svizzera Italiana	http://www.suspi.ch
VSE	Verband Schweizerischer Elektrizitätsunternehmen	http://www.strom.ch

International institutions

EU (RTD)	European Union (RTD-Programme) Community Research & Development Information Service	http://www.cordis.lu
ESA	European Space Agency	http://www.esa.int
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

Private institutions and companies

ESU	Environmental consultancy for business and authorities	http://www.esu-services.ch
EWE	Elektrowatt Engineering	http://www.ewe.ch
NOK	Nordostschweizerische Kraftwerke	http://www.nok.ch

13. Further Internet websites

	Swiss Photovoltaic Website	http://www.photovoltaic.ch
	Swiss Energy	http://www.energie-schweiz.ch
	Energieforschung des Bundes	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 Program Top Nano 21	http://www.ethrat.ch/topnano21/
FOS	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 and Accreditation metas	http://www.metas.ch/
	Swiss Academic and Research Network Switch	http://www.switch.ch
Swissolar	Swiss Task Force for Solar Energy Swissolar	http://www.swissolar.ch
SOFAS	Sonnenenergie Fachverband Schweiz	http://www.sofas.ch
PROMES	Association des professionnels romands de l'énergie solaire	http://www.promes.ch
SSES	Swiss Solar Energy Society	http://www.sses.ch
	US Department of Energy, Photovoltaic Program	http://www.eren.doe.gov/pv/
ISES	International Solar Energy Society	http://www.ises.org

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number: 36487
Contract Number: 76286

Project Title: **Technologische Weiterentwicklung der "mikromorphen" Solarzellen**

Abstract: The present 3-year project is concerned with the further development of the micromorph tandem solar cell technology with the view to obtain industrially relevant manufacturing processes. During 2000, the following main results were obtained:

- TEM investigations on entirely microcrystalline silicon p-i-n solar cells reveal a columnar growth which is critically governed by the substrate conditions.
- Transparent Conductive Oxide (TCO): Upscaling of IMT's LP-CVD ZnO to an area of 30x30 cm^2 ; good film thickness homogeneity, a high haze factor, as well as a high conductivity can now also be obtained on the new large area system
- It has been shown that n-i-p type solar cells deposited at „high" temperatures (350°C) have higher currents and show less light-induced degradation than those deposited at 200 °C (Nevertheless, these effects are minor)
- Thanks to better optical light-trapping and thanks to a reduction in reflection losses, single-junction amorphous silicon p-i-n cells deposited on IMT's in-house LP-CVD ZnO show an improved cell performance compared with solar cells deposited on the best commercially available glass/TCO (SnO_2 Asahi type U2). IMT possesses now a single-junction a-Si:H p-i-n cell technology with a stable efficiency of 9 % (on 1 cm^2 and at a deposition rate of 5 Å/s). Thanks to the excellent properties of IMT's LP-CVD ZnO, such a single-junction cell concept is fully competitive with tandem- or triple-junction cells using amorphous silicon-germanium
alloys.
- Further work on cell deposition and on the monolithic series connection for the micromorph cells has led to a micomorph mini module with 9.1 % stable efficiency (6-segments, active module area 23.3 cm^2)

Duration of the Project: 1.1.2000 – 31.12.2002

Responsible for the project: Prof. Dr. A. Shah

Reporting on the project: Prof. Dr. A. Shah, Dr. J. Meier and co-workers

Address: Institut de Microtechnique
Rue A.L. Breguet 2, 2000 Neuchâtel

Telephone: 032 718 3335 **Fax:** 032 718 3201

http://www-micromorph.unine.ch **Email:** arvind.shah@imt.unine.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme in Photovoltaic Energy Conversion

ANNUAL REPORT 2000

Project Number: ESA contract A0/1-3308/97/NL/NB
ESA contract FE 900 1099/2

Project Title: **Integration of Antennas with Solar Cells (SOLANT)**
Advanced Solar Antennas (ASOLANT)
(Proton irradiation experiments)

Abstract:

The aim of the projects SOLANT / ASOLANT is to combine thin-film solar cells with planar antennas for space applications. The employed thin-film solar cells from IMT are flexible, unbreakable and have an excellent power to mass ratio. Planar antennas as well are a thin, flat and robust technology. Combined, they form a lightweight unit combining the functions of power generation and communication on the same surface.

Results obtained in 2000:

- Prototype SOLANT 6 designed, fabricated and successfully tested. SOLANT 6 is a solar antenna with a lightweight solar module adapted in size and shape to the antenna. The module delivers 0.9 watts at 9.2 volts under realistic space conditions. The antenna is a 6-element circularly polarised slot array for communications at high data rate. Its integrated MMIC amplifier is powered by the solar module.
- Proton irradiation experiments of amorphous, microcrystalline and "micromorph" (microcrystalline / amorphous tandem) solar cells show interesting results : excellent radiation stability for amorphous, reversible degradation for microcrystalline silicon and for micromorph cells. Here the radiation induced defects can be thermally annealed. We expect the cells to attain a 'steady-state' efficiency at temperatures as low as 70°C.

Duration of the project: 1.10.98 – 31.03.2000 (SOLANT)
1.06.00 - 31.05.2001 (ASOLANT)

Responsible for the project: Prof. A. Shah (IMT) - for solar cell activity
Prof. J. Mosig (EPFL) - for antenna activity

Reporting on the project: J. Guillet, M. Goetz

Address: Institut de Microtechnique (IMT)
Université de Neuchâtel
Breguet 2
CH-2000 Neuchâtel

Telephone: 032/718.32.00 **Fax:** 032/718.32.01

http://www-micromorph.unine.ch/ **E-mail:** joelle.guillet@ unine.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number: KTI 4559.1
Contract Number:

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

Abstract

The goal of the project is the design and development of a large area and high throughput coating system for silicon thin film solar cells, based on Plasma Enhanced Chemical Vapor Deposition (PECVD). For an economic production of silicon thin film solar cells it is necessary to coat glass plates of architectural size (one square metre or larger) with a throughput of at least 10 glass substrates per hour.

The three partners in this project are Unaxis/Balzers, the CRPP (Centre de Recherches en Physique des Plasmas) at EPFL Lausanne, and the IMT (Institut de Microtechnique) of the University of Neuchatel.

Duration of the Project: 1.4.2000 - 1.4.2002

Responsible for the project: Dr. Ch. Hollenstein and Prof. M. Q. Tran

Reporting on the project: Drs. Ch. Hollenstein and A. A. Howling

Address: Centre de Recherches en Physique des Plasmas
Ecole Polytechnique Fédérale de Lausanne
1015 Lausanne

Telephone: 021 693 34 71 **Fax:** 021 693 51 76

http:// **Email:** christophe.hollenstein@epfl.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme in Photovoltaic Energy Conversion

ANNUAL REPORT 2000

Project Number : 22816
Contract Number : 68060

Project Title : **Entwicklung von low-bandgap photovoltaischen Zellen**

Abstract :

Thermophotovoltaics (TPV) is a technique which converts heat into electricity by using a thermally heated radiation emitter and photocells. We produced selective radiation emitters made from rare earth oxides. Absolute calibrated radiation spectra were measured and the temperature and spectral emissivity of the emitters were determined. Different measurement setups for the characterisation of photocells in terms of their usability in a TPV system were built: illuminated and dark IV-characteristic, IV-characteristic of single cells and photocell modules working in a TPV test system and measurement of the quantum efficiency. We produced infrared (IR) reflecting filters made from Al doped ZnO. These filters were tested in our TPV system to use them as selective filters for the emitter radiation. The TPV test system developed and built at the PSI was optimised. A new cooling system for the photocells, a more effective selective emitter and an improved interconnection of the cells in the module increased the efficiency of our prototype TPV system to 2.1 %. Simulations were carried out to calculate the efficiency of an optimised TPV system working with silicon photocells and an Yb_2O_3 emitter.

Duration of the Project : December 1998 - November 2001

Responsible for the project : Dr. J. Gobrecht

Reporting on the project : Dr. B. Bitnar

Address : Paul Scherrer Institut
Labor für Mikro- und Nanotechnologie
5232 Villigen PSI

Telephone : 056/ 310 4085 **Fax :** 056/ 310 2646

http://www.psi.ch **Email :** bernd.bitnar@psi.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme in Photovoltaic Energy Conversion

ANNUAL REPORT 2000

Project Number : 22816
Contract Number : 68060

Project Title : **Entwicklung von low-bandgap photovoltaischen Zellen**

Abstract :

Thermophotovoltaics (TPV) is a technique which converts heat into electricity by using a thermally heated radiation emitter and photocells. We produced selective radiation emitters made from rare earth oxides. Absolute calibrated radiation spectra were measured and the temperature and spectral emissivity of the emitters were determined. Different measurement setups for the characterisation of photocells in terms of their usability in a TPV system were built: illuminated and dark IV-characteristic, IV-characteristic of single cells and photocell modules working in a TPV test system and measurement of the quantum efficiency. We produced infrared (IR) reflecting filters made from Al doped ZnO. These filters were tested in our TPV system to use them as selective filters for the emitter radiation. The TPV test system developed and built at the PSI was optimised. A new cooling system for the photocells, a more effective selective emitter and an improved interconnection of the cells in the module increased the efficiency of our prototype TPV system to 2.1 %. Simulations were carried out to calculate the efficiency of an optimised TPV system working with silicon photocells and an Yb_2O_3 emitter.

Duration of the Project : December 1998 - November 2001

Responsible for the project : Dr. J. Gobrecht

Reporting on the project : Dr. B. Bitnar

Address : Paul Scherrer Institut
Labor für Mikro- und Nanotechnologie
5232 Villigen PSI

Telephone : 056/ 310 4085 **Fax :** 056/ 310 2646

http://www.psi.ch **Email :** bernd.bitnar@psi.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme in Photovoltaic Energy Conversion

ANNUAL REPORT 2000

Project Number : BBW Nr. 96.0256
Contract Number : EU Nr. JOR3-CT97-0150

Project title : **Large Area Cadmium Telluride Electrodeposition For Thin Film Solar Cells (LACTEL)**

Abstract : For the last phase of this EU-JOULE project we have compared the structural properties of CdTe layers on different substrates for the development of superstrate and substrate solar cells. The development of substrate type solar cell requires an appropriate substrate for the growth of CdTe layer. Despite of large grain size of CdTe on Mo/glass and Sb_2Te_3/Mo/glass, the cell efficiencies are rather low (<2%). In contrast to this, the same back contact materials when used in superstrate configuration yield high efficiency cells e.g. 11% and 12% cells with evaporated Sb_2Te_3 and Cu/Au contacts. It has been observed that Na has a influence on the microstructure and orientation in CdTe; it can influence the electronic properties by substitutional doping at the cation vacancy site or by forming a donor-acceptor pair.

The quantum efficiency measurements on CdTe superstrate solar cells have revealed that the absorption in CdS window layer is a cause for low currents in our solar cells. In order to increase the efficiency of solar cells above 12% we should decrease the thickness of CdS layer, this may require a bi-layered (high resistance/low resistance) TCO substrate for the deposition of solar cells.

Duration of the project : May 1997-April 2000

Responsible for the project : PD Dr. H. Zogg / Dr. A.N. Tiwari

Reporting on the project : A. Romeo, A.N. Tiwari, D. Baetzner, H. Zogg

Address : Thin Film Physics Group, Laboratory for Solid State Physics, ETH-Building, Technopark, Technoparkstr. 1, 8005 Zürich

Telephone: 01-4451474/1480 **Fax:** 01-4451499

http://www.tfp.ethz.ch/ **E-mail :** tiwari@phys.ethz.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : BBW Nr. 97.0397-1
Contract Number : JOR 3980218

Project title : The CdTe thin film solar cell-improved back contact (CADBACK)

Abstract :
Development of low-Ohmic resistance electrical contact (called back contact) on CdTe is important for high efficiency and long term stable CdTe/CdS solar cells. A metal layer of high work function (>5.7 eV) is required to form an efficient Ohmic contact on p-type CdTe. Most metals don't have high enough work function. Therefore, quasi-Ohmic back contacts have been applied on CdTe. Within the framework of the EU-JOULE program, we have been developing processes for efficient and stable electrical back-contacts on CdTe layers grown by close space sublimation (ANTEC GmbH process) and high vacuum evaporation (ETHZ process). The industrial partner, ANTEC GmbH is setting-up the first CdTe solar module production plant in Europe with a production capacity of 10 MW/yr.

We have developed processes where vacuum evaporated Sb or Sb_2Te_3 buffer and Mo metallization layers are applied on CdTe to form back contacts, solar cells of ~12% efficiency have been obtained. Accelerated stability tests have confirmed that these cells with efficiencies in the range of ~10% to 12% are "stable" for periods corresponding to more than 50 years. During these investigations, it was observed that impurities in CdTe source material may also influence the performance of solar cells. These impurities affect the carrier concentration profile and tend to diffuse across the heterojunction, quite often they are detrimental for the efficiency. Initial efforts were made to develop solar cells where CdTe layers were not chemically etched, cell efficiencies were low because of a surface oxide layer on CdTe. However, evaporated Te-layers improve the efficiency of solar cells.

Duration of the project : June 1999 – May 2001

Responsible for the project : Dr. A.N. Tiwari / PD Dr. H. Zogg

Reporting on the project : D. Baetzner, A.N. Tiwari, A. Romeo, H. Zogg

Address : Thin Film Physics Group
Laboratory for Solid State Physics
ETH Zürich, Technoparkstr.1, 8005 Zürich

Telephone : 01-4451474/1480 **Fax :** 01-4451499

http://www.tfp.ethz.ch/ **E-mail:** tiwari@phys.ethz.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : BBW Nr. 96.0254
Contract Number : EU Nr. JOR3-CT97-0135

Project title : **Wide gap chalcopyrites for advanced photovoltaic devices (WIDE GAP CPV)**

Abstract :
Development of advanced tandem solar cells requires the growth of $Cu(In,Ga)_xSe_2$ (called CIGS) solar cells in a "superstrate configuration". This configuration offers an additional advantage of easier, reliable and low cost encapsulation. Superstrate solar cells with a maximum efficiency of 8.5% were obtained by vacuum evaporation of CIGS absorber on Zn/ZnO:Al layers grown by RF magnetron sputtering. We have developed 15.8% efficiency ZnO:Al/CdS/CIGS/Mo/glass solar cells in a "substrate configuration" but the efficiencies of superstrate solar cells are rather low (~8%).

During the last phase of the project investigations were performed to understand the reasons for low efficiency of superstrate solar cells by characterizing the photovoltaic performance and electronic properties of heterojunctions.

The efficiency of a superstrate solar cell is low because the carrier concentration in the CIGS layer is in the range of ~10^{14} to 10^{15} cm^{-3} which is about 2 or 3 orders of magnitude lower than the optimum concentration of ~10^{17} cm^{-3}. It seems that ZnO:Al layer inhibits the diffusion of Na from the glass substrate. Therefore, extra Na should be co-evaporated during the CIGS deposition to increase the carrier concentration. Light soaking of superstrate solar cells increases their efficiency due to increase in effective carrier concentration in CIGS and reduction of interface trap density near the junction. The efficiency of superstrate solar cells can be increased by increasing the Na concentration in CIGS, optimizing the composition gradient of CIGS and choosing a suitable buffer layer to reduce the interface recombination.

Duration of the project : May 1997-April 2000

Responsible for the project : PD Dr. H. Zogg / Dr. A.N. Tiwari

Reporting on the project : F. -J. Haug, A.N. Tiwari, H. Zogg

Address : Thin Film Physics Group
Laboratory for Solid State Physics
ETH-Building, Technoparkstr. 1, 8005 Zürich

Telephone: 01-4451474/1480 **Fax:** 01-4451499

http://www.tfp.ethz.ch/ **E-mail :** tiwari@phys.ethz.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number : BBW Nr. 97.0398
Contract Number : JOR 3980304

Project title : CIS thin film solar cells on flexible substrates (FLEXIS)

Abstract :
Within the framework of the EU-JOULE project we are developing flexible and lightweight Cu(In,Ga)Se_2 (called CIGS) thin film solar cells. We have developed a novel process where the absorber layer is grown by a co-evaporation method on a polyimide layer, which is spin coated on a NaCl covered glass substrate. After the complete processing of the cells, the NaCl buffer layer is dissolved in water to separate the glass substrate from the ZnO/CdS/Cu(In,Ga)Se_2/Mo/Polyimide stack. CIGS solar cells with a record efficiency of 12.8% were obtained.

The efficiency of solar cells on polyimide is somewhat lower than on glass because the CIGS layers are grown at a low substrate temperature < 450 °C. Therefore, another method for producing flexible CIGS solar cells has been developed which allows the growth of the absorber layers at higher temperatures. With this method, the expensive polyimide can be replaced with transparent polymer. Properties of Mo and CIGS layers were investigated and solar cells were developed. Cells with efficiency of ~8.5% have been measured for the ZnO:Al/CdS/CIGS/Mo/Buffer/SLG solar cell structure. The efficiencies are still low in this initial stage of the development. However, optimization of the deposition processes should result more than 15% efficiency solar cells.

Duration of the project : July 1998 - June 2001

Responsible for the project : Dr. A.N. Tiwari / PD Dr. H. Zogg

Reporting on the project : D. Rudmann, F. -J. Haug,
A.N. Tiwari, H. Zogg

Address : Thin Film Physics Group,
Laboratory for Solid State Physics,
ETH Zürich
Technoparkstr.1, 8005 Zürich

Telephone : 01-4451474/1480 **Fax :** 01-4451499

http://www.tfp.ethz.ch/ **E-mail :** tiwari@phys.ethz.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number:
Contract Number:

Project Title: **Dye sensitised nanocrystalline solar cells**

Abstract: 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 further semiconductor structures or with metals in the Schottky variety. It is recognised that sensitised photoelectrochemical devices offer the only technically and economically credible alternative concept to this solid-state approach. The processes of optical absorption and charge separation take place on distinct sites within these photovoltaic cells. In consequence oppositely charged species are restricted to separate phases, so conventional recombination losses are suppressed. 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 semiconductor provides the charge separation as in the conventional approach, but not the optical absorption. The current state of the technology for these two configurations is reported, as well as recent developments in the area of sensitizers for dye solar cells.

Duration of the Project:

Responsible for the project: Prof. M. Grätzel

Reporting on the project: Dr. Augustin McEvoy

Address: Labo. de la photonique et des interfaces
Département de chimie,
Ecole Polytechnique Fédérale de Lausanne,
CH-1015 Lausanne, Switzerland

Telephone: 021 693 3689 **Fax:** 021 693 4111

http://dcwww.epfl.ch/icp/ICP-2/icp-2.html **Email:** augustin.mcevoy@epfl.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number: PSEL 168
Contract Number:

Project Title: **Freiluftmessungen von Solarzellen neuer Technologie**

Abstract: The project deals with the development of dye-sensitized nanocrystalline solar cells for outdoor use and test in natural environment. Such measurements are of great interest to judge the energy conversion yields of these new photovoltaic devices under realistic reporting conditions. The project has started in the spring of 1999 with preparative work at EPFL. A container for the solar cells was constructed and has been tested at EPFL in open-air experiments. It has meanwhile been installed at the Mont Soleil photovoltaic test station. In parallel, new organic redox electrolytes were developed and tested in the EPFL laboratory to ascertain stable operation of the cells under outdoor conditions. The effect of temperature on the cell performance was measured at full sunlight (AM 1.5, 1000 W/m^2) and one tenth of a sun (AM 1.5, 100 W/m^2). In full sunlight the efficiency remained practically stable over a temperature range from 0°C to 70°C. This distinguishes the nanocrystalline cells from conventional solid state devices whose efficiency declines significantly, i.e. ca 35%, over the same temperature range. A new sealant was identified that is compatible with the electrolyte. Cells were constructed showing stable operation under UV light and/or temperature stress.

Duration of the Project: 1999 - 2002

Responsible for the project: Prof. M Graetzel

Reporting on the project: Prof. M. Graetzel

Address: LPI, EPFL, 1015 Lausanne

Telephone: 021-6933112 **Fax:** 021-693 6100

http://dcwww.epfl.ch/icp/ICP-2/icp-2.html **Email:** michael.graetzel@epfl.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number: JOR3-CT98-0261
Contract Number: OFES N° 98.0042

Project Title: **Long Term Stability of Dye Solar Cells for Large Area Power Applications LOTS-DSC**

Abstract:
The dye solar cell should be UV radiation resistant when intended for high power outdoors applications. The use of filters may reduce cell efficiency and are therefore not the first choice, as an efficient filter has to block off UV and some visible light up to ca. 420 nm or more.
Early experiments at Solaronix showed that the dye solar cell suffered performance reduction, temporarily or permanently after an exposure to UV-A radiation with ca. 10-mW/cm^2 intensity for a few tens of hours. Especially the fill factor dropped by ca. 25% and the cell efficiency went from 5.4% to 4%.
The electrolyte seems to play a role in the UV induced cell performance loss. The use of additives in the electrolyte mixture was investigated. The addition of MgI_2 in the acetonitrile-based electrolyte resulted in more stable current output after UV treatment of the cell. The short circuit current remained practically constant after a 1600 hours UV-A (10 mW/cm^2) treatment. The cell filled with a reference electrolyte without MgI_2, produced only ca. 23% of the initial current after the same UV test.
A kind of recovery effect of the current, fill factor and the yellow appearance of the electrolyte of a cell that was exposed for several days to UV-A was observed. The cell filled only with propionitrile, without MgI_2, recovered its output current to almost initial value after less than 24 hours of relaxing from UV stress.
The recovery effect was not affected when the cell was exposed to visible light without UV-A radiation during the relaxing period of at least 10 hours, respectively 24 hours. It was possible to repeat several times the cycle of UV treatment and relaxing in the dark or under light and the resulted current recovery was accurate with only ca. 10 % of irreversible current drop after 5 cycles.
Up to now, all cell measurements were made in solar simulators emitting continuous light and the current/voltage measurements have been taken with a slow scan method, to avoid inaccurate reading due to capacitive behaviour of the dye solar cell.
Another investigation of the cell characteristics is the observation of the current/voltage decay while the cell is illuminated with a flash lamp delivering ca. 20W/cm^2 light pulse for ca. 1 ms time period.
The LOTS-DSC partner decided that such a flash lamp test facility has to be put up, in order to investigate new and aged cells, in parallel, to other investigation methods like impedance spectroscopy. The Solaronix facility enables to generate visible light flashes with intensity up to ca. 200 suns for 1 ms. Up to 80 cells samples can be measured sequentially with optional white light bias using a sulphur lamp delivering up to 1.5 suns in an area of 50 x 50 cm^2. First trials and experimentation on aged cells will be carried out at beginning of year 2001.
Components interaction: Sealing materials like Bynel form Dupont showed improved thermal withstanding of propionitrile filled cells. Cells heated to 105°C for 3 weeks didn't leak when sealed with the Bynel hot melt.
Module efficiency: A module with 17 interconnected cells showed an efficiency of 4.9 % and a fill factor of 0.62 at full sun and at NOCT of 45°C. The total module active area was 58cm^2, and the assembly technique used screen-printing for the electrode materials.

Duration of the Project: 1998 - 2001

Responsible for the project: Andreas Meyer

Reporting on the project: Dr. Toby Meyer

Address: Solaronix SA
Rue de l'Ouriette 129
CH-1170 Aubonne

Telephone: 021 821 22 08 **Fax:** 021 821 22 89

http://www.solaronix.ch **Email:** andreas@solaronix.com

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number:
Contract Number:

Project Title:	**Photochemische, Photoelektrochemische und Photovoltaische Umwandlung und Speicherung von Sonnenenergie**

Abstract:
Plants are masters in the direct transformation of sunlight into energy. In the ingenious antenna system of the leaf, sunlight is transported by chlorophyll molecules for the purpose of energy transformation. We now succeeded in reproducing a similar light transport in an artificial system on a nano scale. In this artificial system, zeolite cylinders adopt the antenna function. The light transport is made possible by specifically organized dye molecules which mimic the natural function of chlorophyll. Zeolites, some of which occur in nature as a component of the soil, are materials with different cavity structures. We are using miniature zeolite L crystals of cylindrical morphology which show a continuous tube system and we have succeeded in filling each individual tube with a chain of joined dye molecules. Light shining on the cylinder is first absorbed and then transported by the dye molecules inside the tubes to the cylinder end. Tests have shown that this radiationless transport takes place much faster than has been known for green plants so far, for which, however, other ultra fast processes have been reported. Attempts are being made to use the efficient zeolite-based light harvesting system for the development of a new type of thin layer solar cell in which the absorption of light and the creation of an electron-hole pair are spatially separated as in the natural antenna system of green plants.

Duration of the Project:	2000 - 2003

Responsible for the project: Gion Calzaferri

Reporting on the project: Gion Calzaferri, Antonio Currao

Address:
Universität Bern
Departement für Chemie und Biochemie
Freiestrasse 3
3012 Bern

Telephone: (++41) (+31) 631 42 36/26 **Fax:** (++41) (+31) 631 39 94

http://iacrs1.unibe.ch **Email:** gion.calzaferri@iac.unibe.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number: 97.0479
Contract Number: JOR3-CT98-0225

Project Title: **PV en face !**

Abstract:

PV en face ! is contracted as part of the Joule III program of DG XII (JOR3 - CT98 - 0225). Partners are ECOFYS (NL), EPFL (CH), BP (GB) and TFM (ES).

PV en face aims at the development of a number of facade integration design concepts, applying a design strategy with strong emphasis on low-cost, yet high-quality, building integration techniques. Main achievements to be reached include a cost level of 8 - 10 E / Wp and improved market acceptance.

After defining in 1999 a "product market combinations" for PV plants integrated in facades, the LESO started designing an add-on concept for blind walls. This concept is based on a multifunctional frame for PV modules, holding aesthetically standard PV laminates and providing an easy-to-mount interface to the facade.
The main activities for 2000 were then :

- Test the first concept, using prototypes of aluminum frame and stainless steel clips
- Analyse the test results and come up with the necessary improvements
- Manufacture new prototype and test them
- Start marketing process (publications, industry contacts, pilot plants)

Duration of the Project: from 1.8.1998 to 30.10.2000

Responsible for the project: Ch. Roecker

Reporting on the project: F. Schaller

Address: EPFL - Bâtiment LESO, 1015 Lausanne

Telephone: ++41 021 693.43.41 **Fax:** ++41 21 693 27 22

http://lesomail.epfl.ch/ **Email:** christian.roecker@epfl.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number: 10583
Contract Number: 59873

Project Title: **Demosite and Demosite Flat Roofs (part IV)**

Abstract:

Demosite was visited through many visitors at the real site of Lausanne and at the web site on the Internet.

The animated web site www.demosite.ch has been extended with a tutorial section whose aim is to give basic knowledge in building integration of photovoltaics. The first chapter is available. The rest is still under construction.

In 2000, particular attention was focused by medias upon state-of-the art of available photovoltaic technology into the frame of Swiss initiatives campaign.

Three stands were completed or built in 2000. The process to find new exhibitors in order to keep the state of the art at the Demosite was kept running all year long. As a result, two stands should be built by early 2001.

Duration of the Project: 1st.of April 2000 – 31th of March 2002

Responsible for the project: Ch. Roecker

Reporting on the project: P. Affolter

Address: EPFL - Bâtiment LESO 1015 Lausanne

Telephone: ++41 021 693 43 41 **Fax:** ++41 21 693 27 22

http://www.demosite.ch/page/index.html **E-mail** : christian.roecker@epfl.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme in Photovoltaic Energy Conversion

ANNUAL REPORT 2000

Project Number : BBW 99.0039
Contract Number : ERK6-CT-1999-00009

Project Title : **HIPERPB: High Performance Photovoltaics in Buildings**

Abstract :

The aim of the HIPERPB project is to develop high quality and stable thin-film modules based on the CIGS technology. All aspects from cell and module technology to assembling and electrical interconnection and life-time testing will be included. To accelerate the acceptance of the product, aesthetically convincing solutions for building integration combined with high technical quality are required. That is a prerequisite to get into production volumes which makes a low-cost production possible.
An important goal is to increase the public acceptance of photovoltaics – therefore solutions in which the modules form a fully integrated part of the outer skin of the building (roofs and facades) are followed. From the beginning security aspects and building regulations are considered. The electrical interconnection of the elements and the mechanical fixing of the elements have to be developed to fulfil the needs of a safe and user-friendly installation of a solar electricity generating building skin.

Duration of the Project : 01.04.2000 – 1.10.2003

Responsible for the project : R. Neukomm

Reporting on the project : R. Neukomm

Address : Atlantis Solar Systeme AG
Lindenrain 4
3012 Bern

Telephone : +41-31 300 32 15 **Fax :** +41-31 300 30 90

http://www.atlantisenergy.ch **E-mail :** neukomm@atlantisenergy.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number: 36508
Contract Number: 76324

Project Title: **Qualità e resa energetica di moduli ed impianti fotovoltaici. TISO - period VI: 2000-2002**

Abstract:
This year, the LEEE-TISO Centre has started tests on Cycle 7 modules. Cycle 7 concerns 17 types of modules (7 sc-Si 7 mc-Si, 2 a-Si and 1 CIS) which, like previous cycles, have been purchased anonymously and have been chosen from among the most popular ones on the market.
With Cycle 7, a new data acquisition system has been introduced; this allows minute by minute acquisition of electrical and meteorological data for modules operating at MPP. With this system, it is possible to follow the behaviour of modules, which, like on a typical PV plant, have been rack mounted, in relation to various temperature and radiation parameters.
A Sun Simulator for performance measurement (@STC: 1000W/m2, 25°C) of modules has been installed and inaugurated. After initial verification, the simulator is now operational and test procedures are currently being prepared; the measurement procedure @STC should be certified by February 2001.This simulator allows for power verification of Cycle 7 modules every 3 months instead of the 6 month periods for preceding cycles. Measurements @STC have also been carried out for third parties. The solar simulator has also allowed us to study power degradation of a c-Si module which has never been exposed to light: this degradation occurs in the first hours of exposure of the module.
A roof, which has recently been repaired and made accessible, has had a Sun tracker installed on it which will allow an energy rating study for different and representative meteorological conditions.
Periodic measurements of the 3 TISO plants (10, 4 and 0.5kW) have continued; the 10kW TISO plant is being monitored more closely since it is the object of another research project (MTBF); in the 4kW plant, the a-Si modules which have been thermally isolated at the back have shown an increase in performance of around 6%.
The content of the internet site has been enhanced and the links section has been augmented.

Duration of the Project: 1 January 2000 - 31 December 2002

Responsible for the project: Giorgio Travaglini

Reporting on the project: N. Cereghetti, D. Chianese, S. Rezzonico, G. Travaglini

Address: SUPSI, DCT, LEEE-TISO
6952 Canobbio
Switzerland

Telephone: 091/ 935 13 55 **Fax:** 091/ 935 13 49

http://leee.dct.supsi.ch **Email:** leee@dct.supsi.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number: BBW 99.0579
Contract Number:

Project Title: **Mean Time Before Failure of Photovoltaic modules (MTBF-PVm)**

Abstract : The 10kW sc-Si PV plant, installed in 1982 on the roof of the LEEE-TISO, consists of 252 ASI 16-2300 Arco Solar modules, in 12 strings of 21 series connected panels. Since its realization the array operation has been continuously monitored by TISO and periodic electrical measurements on a batch of 18 reference modules have been performed at the ESTI Laboratory (EC, JRC Ispra, RE Unit).
In proximity of the 20-year design life of the plant, a collaboration between TISO and ESTI has been started to determine the Mean Time Before Failure (MTBF) of the system and to investigate the physical degradation mechanism in action.
For this purpose, detailed visual inspections and IR analysis, strings and individual panels performance measurements, analysis of evolution of system performance ratio over time and correlation of all these data, are the main works that TISO is going to develop within the MTBF project. Results of a recent visual inspection show partial or complete yellowing on more than 95% of investigated modules, delamination of encapsulant on about 90% of the plant (on 20% of these samples delamination forms a continuous path between frame and circuit; this is a major defect according to CEI/IEC 61215) and several hot-spotted cells.
Modules of two strings of the plant have been individually measured with the LEEE-TISO Sun Simulator; a first data analysis showed interesting different electrical behaviours between modules with and without visual defects.

Duration of the Project: October 1999 - December 2000

Responsible for the project: Dr. Giorgio Travaglini

Reporting on the project: Antonella Realini

Address:
LEEE-TISO
SUPSI-DCT
CP 110
6952 Canobbio

Telephone: 091 935 13 52 **Fax:** 091 935 13 49

http://www.leee.dct.supsi.ch **Email:** antonella.realini@dct.supsi.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number: 2744
Contract Number: 61703

Project Title: **Qualitätssicherung von Photovoltaikanlagen**
Quality assurance of PV-plants

Abstract:

Most important results in 2000

- Completion of development of a solar generator simulator (Uoc 750V=, Isc 8A=, Pmax 5kW) by students during their diploma thesis.
- Tests of some grid connected inverters at different DC voltages using the new solar generator simulator (e.g. SMA Sunny Boy SWR 1500, OK4E-100, Convert 4000).
- Compilation of the most important project results in the final report.
- Completion of the development of a high power (750V=, 40A=, 25kW) solar generator simulator to improve the inverter test site at HTA Burgdorf in a project funded by Berner Fachhochschule Successful test of this new device with an inverter Solarmax DC30+ operating at 25kW in fall 2000. The PV laboratory can now perform tests of PV inverters much faster and more thoroughly in the future.
- Several publications about test results.

Duration of the Project: April 1st, 1997 to March 31th, 2000 (extended)

Responsible for the project: Hochschule für Technik und Architektur Burgdorf,
Prof. Dr. H. Häberlin

Reporting on the project: H. Häberlin

Address: Abteilung Elektrotechnik
Jlcoweg 1
400 Burgdorf

Telephone: ++41 34 426 68 11 **Fax:** ++41 34 426 68 13

http://www.hta-bu.bfh.ch/e/pv/pv-indd.htm

Email: heinrich.haeberlin@hta-bu.bfh.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme in Photovoltaic Energy Conversion

ANNUAL REPORT 2000

Project Number: 39949
Contract Number: 79765

Project Title:	**Langzeitverhalten von netzgekoppelten Photovoltaikanlagen 2** **Long Term Behaviour of Grid connected PV Systems 2**

Abstract:

Purpose and Goals of the Project during 2000:

- Maintenance of the monitoring systems used in the project
- Proposal of the new project „Long Term Behaviour of Grid connected PV Systems 2"
- Analysis of operation and possible problems at all grid connected PV plants monitored in the project
- Analysis of inverter reliability in all PV plants monitored in the project

Most important results in 2000

- In 1999 and 2000, energy production of PV plant Jungfraujoch was affected slightly by the replacement of the windows of the research station. In 1999 the plant produced 1330 kWh/kWp.
- Inverter reliability of grid connected PV plants is equal compared to 1999 (majority of defects were observed at older inverters that have been operated for several years)
- Installation of a recording device for measuring energy production of the new PV plant Alterspflegeheim 1 + 2 in Burgdorf

Duration of the Project:	01.06.2000 – 31.08.2003

Responsible for the project: Prof. Dr. H. Häberlin
Hochschule für Technik und Architektur
(HTA) Burgdorf

Reporting on the project: C. Renken and H. Häberlin

Address: Jlcoweg 1, CH-3400 Burgdorf

Telephone: +41 34 426 68 11 **Fax:** +41 34 426 68 13

http://www.hta-bu.bfh.ch/e/pv/pv-inde.htm

Email: heinrich.haeberlin@hta-bu.bfh.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme in Photovoltaic Energy Conversion

ANNUAL REPORT 2000

Project Number : BBW 97.0301 **EU-Nr.:** JOR3 CT98 0217

Project Title : PV-EMI: Development of standard test procedures for electro-magnetic interference (EMI) tests and evaluations on photovoltaic components and plants

Abstract :
The objective of the "PV-EMI-Project" is the realisation of a standardized European approach towards the electromagnetic compatibility of solar photovoltaic systems by means of elucidating the legal situation, developing measuring concepts, doing concrete sample measurements and realizing information dissemination to standardization committees and final users (industries, SMEs, plant owners). Project partners: Fraunhofer ISE (BRD), HTA Burgdorf (CH) and KEMA (NL).

Realized work in 2000 (HTA Burgdorf)

- **Extended measurements of induced voltages at real modules and models of PV modules:**
  - Concerning induced voltages, three different types of modules could be identified: additive modules and compensating modules with even and with odd row numbers
  - Test results show that a metallic frame reduces the induced voltages in single modules by a factor 2.5 to 6 (at larger distance between 3 and 5) compared to identical modules without frames.
  - Tests with models of arrays consisting of several modules with metallic frames showed that also the voltages induced in the array wiring and in the array as a whole are reduced by a similar factor due to the frames.
  - By (intended or unintended) grounding of metallic module frames large ground loops are created, in which very large common mode voltages may be induced. Hints are given how to handle and reduce such voltages.
- **Measurement of RF emissions in the laboratory**
  - Based on the on-site measurements, calculations and simulations performed by the project partners, new values and limits for a DC-LISN were defined by the project team:
    DC-LISN: Common mode impedance Z_{CM} = 250Ω (+100%, -50%)
    Differential mode impedance Z_{DM} = 100Ω (+100%, -50%)
    Limits for DC-side (quasi-peak): 150kHz ... 500kHz: 80dBμV
    500kHz ... 30MHz: 64dBμV.
  - Measurements at HTA Burgdorf at some good inverters from experienced manufacturers showed that these new limits can be respected without problems.
  - HTA Burgdorf will try to realise such a DC-LISN with the above values as soon as possible after the end of the project

Duration of the Project : 01.06.1998 – 30.05.2000 (31.08.2000)

Responsible for the project : Prof. Dr. H. Häberlin

Reporting on the project : Prof. Dr. H. Häberlin, R. Fischer, Dr. R. Minkner

Address : Berner Fachhochschule , Hochschule für Technik und Architektur (HTA) Burgdorf, Jlcoweg 1, CH-3400 Burgdorf (ehemals ISB)

Phone : +41 (0)34 426 6811 **Fax :** +41 (0)34 426 6813

http://www.hta-bu.bfh.ch/e/pv/pv-inde.htm

E-mail : heinrich.haeberlin@hta-bu.bfh.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number: 16868
Contract Number: 66402

Project Title: **New Generation of Hybrid Solar PV/T Collectors**

Abstract:
The aim of this study was to verify if commercial amorphous PV modules can be directly used as absorber of a water based PV/T collector. In order to have a good thermal efficiency and a reduced risk of damage, the absorber should have sufficient absorption and must withstand a stagnation temperature of about 150°C for extended periods of time.

Absorption values of between 78% and 90% have been measured on commercially available a-Si samples. This is more than minimally required for the PV/T application.

Several samples withstood thermal cycling of 10 hours at 210°C without a significant decrease of efficiency. This excellent stability is related to the absence of aluminium. For samples with back contacts made of aluminium, an oxydation layer acts as good protecting diffusion barrier. This was confirmed by a prototype of a-Si collector that was put under the sun without cooling all summer.

Further evaluation for new encapsulating or covering top layer materials should be carried out. A trade-off between a high optical absorption coefficient in the visible and near IR range and a low emission coefficient in the far IR may become necessary.

Duration of the Project: June 1998 - September 2000

Responsible for the project: Ch. Roecker

Reporting on the project: P. Affolter

Address: EPFL - Bâtiment LESO 1015 Lausanne

Telephone: ++41 021 693.43.41 **Fax:** ++41 21 693 27 22

http://lesomail.epfl.ch/ **Email:** christian.roecker@epfl.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number: 980216 (BBW)
Contract Number: EU Nr. SME/1479/97-DE

The potential of PV noise barrier technology in Europe

ABSTRACT:
Photovoltaics is expanding into new market segments. Photovoltaic noise barriers (PVNB) along motorways and railways permit today one of the most economic applications of grid-connected PV with the additional benefits of large scale plants (typical installed power: more than 100 kWp) and no extra land consumption. The aim of this study is to reveal the large potential that can be exploited for PV on noise barriers with the overall objective of raising the share of renewable energies for the EU´s electricity market. In contrast to many PV-potential studies published before, this proposal is focusing on PVNB only, as one of the cheapest ways to implement large scale grid-connected PV installations.

The Short term/extrapolated potential
The short-term potential for Switzerland, Germany and NL is approx. 140 MWp PV along roads and 145 MWp PV along rails (see figure 1).This results for all EU members to an extrapolated potential of 1145 MWp PV along roads and rails. If the national policy changes in France, Italy and United Kingdom to a European extrapolation, the expected potential in France is 96 MWp, in Italy 170 MWp resp. in United Kingdom 385 MWp.

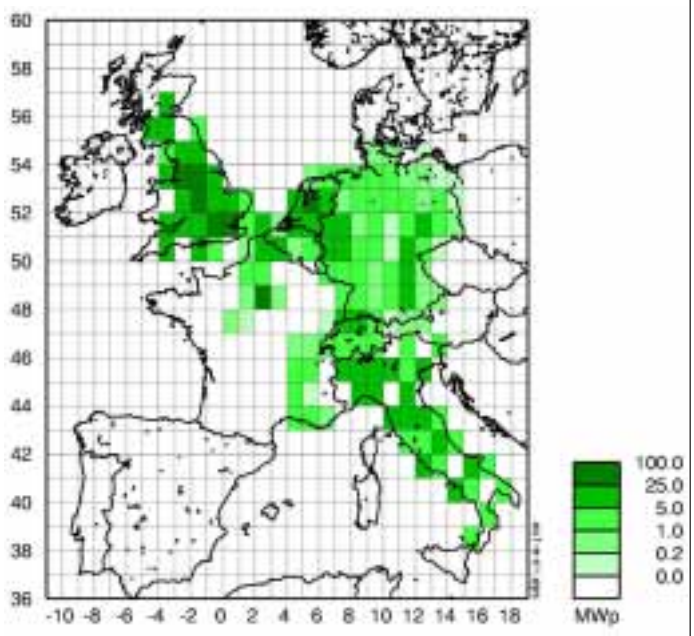

Figure 1: Extrapolated potential of installed power of PV along rails & roads in all six countries

Duration of the project: June 1998 to Dezember 1999

Responsible for the Project: TNC Consulting AG
Reporting on the Project: Th. Nordman, A. Frölich
Address: Seestrasse 141, CH - 8810 Erlenbach
Telephone: 01 - 991 55 77 Fax: 01 - 991 55 78
E-Mail: nordmann@tnc.ch, froelich@tnc.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme in Photovoltaic Energy Conversion

ANNUAL REPORT 2000

Project Number: BBW 97.0542
Contract Number: JOR3-CT98-0230

Project Title:
PVSAT: Remote performance check for grid connected PV systems using satellite data

Abstract:

The PVSAT procedure will provide an operational, low cost, long-term surveillance for small PV systems, applicable to any site within Europe. There are no additional hardware expenses at the individual systems, the accuracy will be stable over the whole geographic region. Through the early detection of faults or malfunction, the energy output of a large number of systems may be optimised remarkable.
PVSAT operates as follows:

- Images of the geostationary METEOSAT satellites will be used to derive irradiation values for the individual PV-Plant site.
- Using the satellite irradiation values and individual configuration information on each PV system, individual target yield values are determined.
- The results will be distributed automatically via postcard, fax or e-mail.
- The operator compares the target value with the actual production.

This procedure will remind the system operator periodically to check the performance of his installation.
The accuracy of satellite data come to +-10%. Only in low radiation periods (H<1.5kWh/m^2 per day), the satellite image derived irradiation data probably overestimate the real solar energy availability. In the reporting year the system was implemented with a total of about 70 pilot participants in the Netherlands, Germany and Switzerland.

Contractors
Frauenhofer ISE, Freiburg (D)
Enecolo AG, Mönchaltorf (CH)
Utrecht University, Utrecht (NL)
Universität Oldenburg, Oldenburg (D)

Subcontractors
Energiebüro Christian Meier (CH)
Energy Consulting, Aix en Provence (F)
Organisatie voor Duurzame Energie (NL)
Fachhochschule Magdeburg, Magdeburg (D)
Deutscher Fachverband Solarenergie e.V. (D)
Deutsche Gesellschaft für Sonnenenergie e.V. (D)

Duration of the Project: 1. Juni 1998 – Juli 2001

Responsible for the Project: Enecolo AG
Reporting on the Project: Peter Toggweiler, Urs Brügger
Address: Enecolo AG
Lindhofstr. 52, 8617 Mönchaltorf
Telephone: 01 / 994 90 01 **Fax:** 01 / 994 90 05
http://www.solarstrom.ch **E-mail**: info@enecolo.ch
http://www.pvsat.de

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme in Photovoltaic Energy Conversion

ANNUAL REPORT 2000

Project Number: BBW 00.0308
Contract Number: ERK6-CT1999-20001

Project Title:	**Thematic Network: Energy in the Built Environment (EnerBuild)**

Abstract:
The characteristics of the European building industry and the energy market require that very deliberate emphasis must be given to technology transfer and dissemination if new and improved energy technologies are to have the appropriate impact. EU RTD programmes during the past quarter century have made important contributions to advancing innovative technologies and concepts. Developing on this important foundation, the EnerBuild RTD Thematic Network will provide a major impetus to the process of bringing about change in the energy efficiency of European buildings.

To enhance co-operation among energy RTD projects addressing the built environment supported in the EC's Fourth and Fifth Framework programmes, the EnerBuild RTD Thematic Network will have the following objectives:
• To deliver the results of past and current research to potential users in the most important sectors with the greatest dissemination potential, with the overall objective of reducing emissions and improving the energy efficiency of the built environment in Europe
• To facilitate collaboration and exchange among EC-supported research projects
• To help maintain the technical and industrial content of future European energy-related building research and to help identify research priorities
• To form links with relevant targeted R&D actions and other Thematic Networks with a view to maximising the effectiveness of the problem-solving effort, and to minimise overlap and facilitate communications between national and EC-funded activities
• To encourage the formation of new RTD partnerships between stakeholders in construction
• To evaluate the effectiveness of different disseminating strategies and media.

The Network comprises primarily JOULE and CRAFT building-related energy R&D projects, and FP5 projects particularly within Key Action 6. Projects are grouped in carefully-constructed dynamic thematic groups co-ordinated by internationally-respected experts, and considerable emphasis is accorded to inter-group opportunities and horizontal dimensions such as socio-economic and other cross-cutting objectives at the European level. The entire process is guided by a formal Steering Committee (Enecolo is the Swiss member) deciding strategic matters and including senior representatives of European industrial, professional and research federations and associations and managed by a group with two decades of experience and achievements in the Network's topic.
A diverse but integrated series of measures will: Identify potential winning technologies, Target markets and study their requirements, identify and implement coherent technology transfer and promotion strategies and evaluate the results.

Duration of the Project:	April 2000 – April 2002

Responsible for the Project: Enecolo AG
Reporting on the Project: Peter Toggweiler
Address: Enecolo AG
Lindhofstr. 52, 8617 Mönchaltorf
Telephone: 01 / 994 90 01 **Fax:** 01 / 994 90 05
http://www.solarstrom.ch **E-mail**: info@enecolo.ch
http://www.enerbuild.net

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : BBW 98.0070
Contract Number : JOR 3980204

Project Title : **PHOTO-VENT: Development of PV-powered smart natural ventilation devices**

Abstract :

Within the PHOTOVENT project, the work is focused on the development of intelligent ventilation strategies for dwellings and non-domestic buildings. It is expected to have at the end of the project new systems which allow to improve at the same time the indoor climate conditions in buildings as the energy use of these systems.

Duration of the Project : 01.09.1998 – 30.11.2000

Responsible for the project : A. Eckmanns

Reporting on the project : A. Eckmanns

Address : Atlantis Solar Systeme AG
Lindenrain 4
3012 Bern

Telephone : +41-31 300 30 80
Fax : +41-31 300 30 90
http://www.atlantisenergy.ch
E-mail : info@atlantisenergy.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : 39489
Contract Number : 79285

Project Title : Literaturstudie Ökobilanz Photovoltaikstrom und Update der Ökobilanz für das Jahr 2000

Abstract :
Solar radiation is a source for renewable energy and for the production of electricity in photovoltaic appliances (PV). The aim of this project is to provide up-to-date data for the environmental impacts of electricity production with photovoltaic appliances based on a literature study. In a first part, life cycle assessment (LCA) studies from different authors are reviewed. The information is used to elaborate a life cycle inventory from cradle to grave for PV-electricity production in Switzerland. An LCA dated from 1996 is used as a basis for the inventory. This study is complemented as far as possible with new data mainly from other studies. Only few data were available for today's production processes. Additional environmental impacts i.e. due to the infrastructure for module production and the effluents from wafer production are considered for the inventory. The study describes the production of PV-appliances with an assumption for the best available technology. For some stages this might underestimate the environmental impacts in comparison to average facilities installed today. The new assumptions lead to a considerable reduction of energy uses and environmental impacts in the life cycle in comparison to the reference study mentioned above. This is mainly due to the assumption of new production possibilities for solar grade silicon used for solar cells and due to the assumption for a more efficient use of the raw silicon in wafer production. With the new data, the energy payback time for photovoltaic appliances in Switzerland lies between 4.5 and 6 years. The life cycle inventory can be used for the comparison of environmental impacts due to electricity production from different energy resources and with different means of production. But also with this update its is still necessary to investigate up-to-date and real data for all production stages in the life cycle based on information from today's production facilities.

Duration of the Project : 2000

Responsible for the project : Dr. Rolf Frischknecht

Reporting on the project : Dr. Niels Jungbluth, Dr. Rolf Frischknecht

Address : Kanzleistrasse 4
CH-8610 Uster

Telephone : 01 940 61 32 **Fax :** 01 940 61 94

http://www.esu-services.ch **Email :** jungbluth@esu-services.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number: NNE5-1999-00483
Contract Number:

Project Title: **Combined Project on Multi-User Solar Hybrid Grids**

Abstract:

Experiences with village power supply world-wide show deficiencies in technical and social issues. Especially those basing on renewable energy sources with limits on the energy provision. They still need improvements in components, design, installation, operation and in user knowledge, acceptance of limits, behavioural adaptations and in social organisation around the new technology. We want to demonstrate and improve Multi-User Solar Hybrid Grids (MSGs) for their application in Europe and world-wide to provide power for domestic and productive uses, public lighting etc., to utilise renewable energy reducing consumption of fossil fuels including CO2 and noise reduction, prevent dangerous transports of fuel and thus expand the markets for European companies.

With a specially designed energy dispenser and our socio-technical approach we can reach sustainability, can overcome the often occurred overuse and improve the consumer's satisfaction. In the research part we are improving this energy dispensing and social strategies for higher efficiency of MSGs and increase of the consuming of renewables.

Duration of the Project: 1999 - 2002

Responsible for the project : PD Dr. Hans-Joachim Mosler

Reporting on the project : PD Dr. Hans-Joachim Mosler

Address : Sozialpsychologie I
Universität Zürich
Plattenstr. 14
8032 Zürich

Telephone : 01/6342118 **Fax :** 01/634 4931

http://www.psych.unizh.ch/sozpsy/personal/mosler.html

Email: mosler@sozpsy.unizh.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number: 11'427
Contract Number: 76'585

Project Title:	**SWISS Contribution to the IEA Implementing Agreement on Photovoltaic Power Systems (PVPS), TASK1**

Abstract :
Support of Task 1's aim – to guarantee the exchange of information between the countries involved in the PVPS- Program – with the following publications, meetings and workshops:

- The National Survey Report NSR (Basis for the International Survey Report)
- The PV Statistics for 1999 reveal important installed-power increases in all PV sectors. There are now 13.4 MWp installed. Switzerland is still world leader in per capita installed PV-Power. PV system-prices lie between CHF 10.00 / Wp (On-grid) and CHF 20.- / Wp (small off-grid systems).
- The PV Power magazine was distributed to 250 subscribers.
- Meetings: Swiss PVPS experts met twice before the ExCo meetings. These meetings have proved valuable, and information exchange from task to task has been improved.
- Task 1 met in Naples and Munich with the main work put into the organization of the workshop "Added Value of PV Systems" held in Glasgow on the 5th May 2000. The ISR was ready for distribution by the end of September

Duration of the Project:	1998 -

Responsible for the project: Pius Hüsser

Reporting on the project: Pius Hüsser

Address: Nova Energie
Schachenallee 29
5000 Aarau

Telephone: xx41 (0) 62 834 03 00 **Fax:** xx41 (0) 62 834 03 23

http://www.novaenergie.ch **Email:** pius.huesser@novaenergie.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number: 14805
Contract Number: 67820

Project Title: **IEA - Photovoltaic Power Systems (PVPS), Task II, Swiss Cooperation**
Operational Performance, Maintenance and Sizing of PV Power Systems and Subsystems

Abstract:

Switzerland has committed itself to take part in the Photovoltaic Power Systems (PVPS) programme of the International Energy Agency (IEA), Task II. The aims of the IEA-PVPS-Task II are outlined in the IEA PVPS Implementing Agreement of April 1993.

The overall objectives of the Task II 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 database and collection of new PV systems
- Evaluation of PV Systems
- Improving PV System performance

The first Phase of the works was completed in 2000. The final Report of these activities was approved by the ExCo in April 2000 and is published now.

In spring 1999 a new workplan for the continuation of Task II was presented to the ExCo. At the PVPS Executive Committee meeting in May 99 it was agreed to extend the activities of Task II for another five years, starting in 1999.

This annual report gives an overview of the status of the work, the contents of the international PV database, PVbase, and it provides some results of the work of phase I.

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

Duration of the Project: Jan. 1999 to Dec. 2001

Responsible for the project: TNC Consulting AG

Reporting on the project: A. Frölich, L. Clavadetscher, Th. Nordmann

Address: TNC Consulting AG
Seestrasse 141
8703 Erlenbach
Switzerland

Telephone: 01 / 991 55 77 **Fax:** 01 / 991 55 87

http://www.tnc.ch **Email:** froelich@tnc.ch, nordmann@tnc.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number : 35550
Contract Number : 75310

Project Title : **IEA PVPS Task III**
Use of photovoltaic systems in stand-alone and island applications

Abstract :

IEA PVPS Task III program focuses on quality assurance (QA) implementation and undertakes the following activities:

- Collect, analyze and disseminate information on the technical performance and cost structure of stand alone PV systems.
- Share the knowledge and experience gained in monitoring selected national systems

Provide guidelines for improvement of the design, construction and operation of SAPV systems.

One important objective reached this year has been a draft on **Survey of National and International Standards, guidelines and QA Procedures for Stand-alone PV Systems.** This paper presents all the known standards on isolated PV systems of the following countries: Australia, Canada, France, Germany, Japan, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and the United States of America. This important contribution includes among others International QA procedure and best pratices, Japanese standards and standards under development.
A second objective is a proposal for **Monitoring Guidelines for Case Studies.** This second paper will facilitate the work of any company which needs to implement testing or monitoring equipment in a stand-alone PV system.
Other contributions achieved in 2000 are:

- a paper on **Performance and Quality of Service Evaluation of PV Hybrid Plants of Individual Users Operated by SEBA** which describes the experience on PV rural electrification in Spain.
- a simple **Data Base on Failures of PV Systems** which could ultimately be summarized in to a guide of what works and what does not work in SAPV systems – shortly to be presented on the web.

Duration of the Project : 9/1999 – 8/2001 1st phase

Responsible for the project : Dynatex SA
Reporting on the project : Michel Villoz
Address : Moulin 5
1110 Morges
Telephone : 021 802 62 00 **Fax :** 021 802 62 01
http://www.task3.pvps.iea.org **E-mail :** dynatexsa@infomaniak.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number: 36612
Contract Number: 76427

Project Title: **IEA PVPS Task V: Grid Interconnection of Building- Integrated and other dispersed Photovoltaic Power Systems**

Abstract:

Task V is a working group of the International Energy Agency (IEA), Implementing Agreement on Photovoltaic Power Systems (PVPS). The title of the working group is "Grid Interconnection of Building Integrated and Other Dispersed Photovoltaic Power Systems" and had started its activity in 1993 to investigate the grid interconnection issues through international collaborations. The subtasks 10, 20 and 30 have been concluded successfully End of 1998. Several reports are available, please contact the address below.

The Task V extension (Subtask 50 "Study on Highly Concentrated Penetration of Grid Interconnected PV Systems") has following objectives. To assess the net impact of highly concentrated PV systems on electricity distribution systems and to establish recommendations for both distribution and PV inverter systems to enable widespread deployment of solar energy. Switzerland is involved as co- working country in reporting of PV system grid- interconnection technology, evaluation of islanding detection methods, maximum penetration level of PV systems and financial aspects for PV systems.

In the activity 'Research on islanding' a survey was issued, which deals with islanding detection methods. A good participation was noticed from Switzerland, thanks to our national inverter manufacturers Sputnik, ASP and Hardmeier electronics.

In the Netherlands a one-year measurement was done to determine the probability of an islanding situation with a multiple PV system in a normal residential grid. Measurements were taken and stored every second. The number of possible islanding conditions, categorised by how well loads are matched to PV output, are determined for several penetration levels of PV. Information was also obtained on the length of time that an island condition could be sustained. The risks of islanding will be determined via fault-tree analysis. Detection schemes for islanding are obtained via an international survey. Together with the results from islanding tests at Sandia National Laboratories conclusions can be given on the effectiveness of these detection schemes.

This action is concluded and all the data is being analysed. Using this information, adequate detection methods for islanding will be studied and reported on. The work could result in more cost-effective deployments of grid-connected PV systems.

Based on the results a workshop will be held on the new islanding experiences. The workshop will take place in the Netherlands in Sept. 2001. The outcome of the ongoing major work will provide a better understanding of the probability of the islanding phenomena and should lead towards cost-effective methods for the detection. All other activities are proceeding according to the work plan and draft reports will be presented at the next meeting in Paris or UK (Feb. 2001).

Duration of the Project: Subtask 50: 1. Jan. 99 – 31. Dec. 01

Responsible for the project: ewz (Elektrizitätswerk der Stadt Zürich)

Reporting on the project: Daniel Ruoss (Enecolo AG), Sergio Taiana

Address: ewz, Tramstr. 35, 8050 Zürich

Telephone: 01 / 319 44 55 **Fax:** 01 / 319 41 97

http://www.ewz.ch **Email:** sergio.taiana@ewz.stzh.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme in Photovoltaic Energy Conversion

ANNUAL REPORT 2000

Project Number: 20552
Contract Number: 76586

Project Title: **IEA PVPS Task VII: Photovoltaic Power Systems in the Built Environment**

Abstract:

Task VII is a working group of the International Energy Agency (IEA) and started its activity in 1997 and will run till April 2002. The activities are organised in 4 Subtasks (Architecture, system technologies, non-technical barriers, demonstration and dissemination). Task objective are to enhance the architectural quality, the technical quality and the economic viability of PV systems in the built environment and to assess and remove non- technical barriers for their introduction as a significant energy option. It is expected that the successful integration of PV systems into built environment will contribute significantly to the future spread of PV.
Primary focus is on the integration of PV into the architectural design of roofs and facades of residential, commercial and industrial buildings and other structures in the built environment (such as noise barriers, parking areas and railway canopies). Further focus is put on other market factors, both technical and non-technical, that need to be addressed and resolved before wide spread adoption of PV in the built environment will occur.

Switzerland is actively involved in the Case Studies (Subtask 1), providing extensive information on the project ' PV installation ABZ in Zurich' and on a project applying a new mounting system for green roofs called SOLGREEN. These case studies will be published mid 2001 in a book and will also be available on the Internet (www.task7.org). A database with several installation examples is accessible for the public under www.task7.org. Under the IEA collaboration the Swiss simulation tool PVSYST is being tested in various case studies and is the official simulation tool of the Task.

All activities within the Subtask 2 'system technologies' are being co-ordinated by Enecolo AG. Following work was done in 2000: Proceedings of the workshop organised at the EPFL in Lausanne (1999) were published and can be ordered. A further workshop was organised in September in Stockholm addressing the topic 'non building structures'. Input from the workshop will take place in the draft report of the activity.

In co-operation with NET AG, a report has been prepared addressing the PV potential in the built environment for several selected IEA countries. This document will be included in the Subtask 3 report, which will be published beginning 2001 and is dealing with issues like economics, marketing and publicity strategies concerning non- technical barriers.

An important topic in the Subtask 4 work is the operation of the DEMOSITE in Lausanne, co-ordinated by EPFL- LESO. The site has now around 30 systems on display, and is also available for "virtual visits" on www.demosite.ch. In Subtask 4, the major work in the year 2000 was the International Solar Electric Building Conference held in Sydney, March 8.- 10. Further activity was an International Design competition organised, 5 entries from Switzerland resulted. Winners from Switzerland: Marcel Ferrier, Architect and the Solarsail Münsingen as exhibition prize.

Duration of the Project: 1. Jan. 1997 – April 2002

Responsible for the Project: Enecolo AG
Reporting on the Project: Peter Toggweiler, Daniel Ruoss
Address: Enecolo AG
Lindhofstr.52,
8617 Mönchaltorf
Telephone: 01 / 994 90 01 **Fax:** 01 / 994 90 05
http://www.solarstrom.ch **E-mail**: info@enecolo.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number:
Contract Number: seco RK V/HAFO/11141

Project Title: **Swiss Contribution to IEA PVPS Task 9 – Deployment of Photovoltaic Technologies: Co-operation with Developing Countries – Phase I**

Abstract:
With the support of the State Secretariat for Economic Affairs (seco), this project provides the Swiss contribution to IEA PVPS Task 9. The objective of Task 9 is to further increase the overall rate of successful deployment of PV systems in developing countries. This will be 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.

Beyond the contribution to 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
4. increasing Swiss activities in the field of PV technology co-operation

Duration of the Project: October 1999 – December 2002

Responsible for the project: Stefan Nowak, NET AG
Alex Arter, entec AG
Reporting on the project: Stefan Nowak

Address: NET Nowak Energie & Technologie AG
Waldweg 8, 1717 St. Ursen

Telephone: +41 (0)26 494 00 30 **Fax:** +41 (0)26 494 00 34
http: **E-mail:** stefan.nowak.net@bluewin.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : 23783
Contract Number : 77264

Project Title : **Global Approval Programm PV GAP**

Abstract : PV GAP is a not-for-profit organisation, registered in Switzerland, that approves the quality of PV systems and components. PV GAP also promotes the development and utilisation of internationally accepted specifications (PVRS) and standards (IEC) that promote the integration of quality into all aspects of PV energy delivery. The organisation encourages international reciprocity of national specifications for manufacturers, testing laboratories and accreditation of training programs in installation, operation and maintenance for PV practitioners. PV GAP's mission is to promote and encourage the use of such internationally accepted standards, quality management processes and organisational training in the design, fabrication, installation, sales and services of PV systems. To this end, PV GAP partners with PV and related industries, international organisations, testing laboratories, government agencies, financing institutions, non-governmental organisations, and private foundations, in developing and developed countries.

During the past year, further major milestones were achieved such as:

- growing acceptance by the industry and financial institution to realise the inherent value of international recognised quality system and label, which will improve quality, the perception by the end user that PV systems are reliable options for generating electricity,
- further clarified and simplified procedures to qualify for PV GAP approval and PV GAP Mark / Seal,
- first products being approved to PV GAP, and therefore the procedure was already successfully applied, braking ice for accelerated introduction of PV GAP
- PV GAP training manual was completed, and is translated in several languages, helping small companies to install a management system, which enables the companies to be approved to ISO 9000, a prerequisite for IECQ and PVGAP approval
- There is an increasing number of testing laboratories accredited and getting PV GAP/IECQ approval, to certify products to obtain the PVGAP PV Quality Mark and Seal.

Duration of the Project : 1.4.2000 – 30.11.2001

Responsible for the project : Markus Real

Reporting on the project : Markus Real

Address : Alpha Real AG,
Feldeggstrasse 89, 8008 Zürich

Telephone : +41 1 383 02 08 **Fax :** +41 1 383 18 95

http://www.pvgap.org **Email :** alphareal@access.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : 17222
Contract Number : 56790

Project Title : **Pilotanlage 2kWp für modulintegrierte Wechselrichter**

Abstract :

Pilot Plant 2 kWp for module-integrated inverters

The aim of the project has been to test the new 200 W module-integrated inverter for direct grid-coupling developed by the Hochschule für Technik und Architektur Biel / Sputnik Engineering Nidau / Atlantis Energy Bern (final report DIS 2754).
10 modules (2 kWp) have been coupled March 1998 with the network of the Energy Services of the city of Biel. The main goals of the test were to check the reliability of the inverter, the performance of the system and to recognize possible disfunctions of the inverter and get information in order to optimize construction data.
The operation of the integrated system has been observed by a powerful monitoring system from november 1998 to march 2000.
The system and the inverter have shown a very good reliability and worked without any perturbation during the whole test period of more than one year. A detailed analysis of test results can be found in the end report of november 2000.

Duration of the Project : October 1996 - March 2000

Responsible for the project : Hochschule für Technik und Architektur Biel

Reporting on the project : Prof. Dr. V. Crastan

Address : Quellgasse 21, Postfach 1180, 2501 BIEL

Telephone : 032 / 341 09 93 **Fax :** 032 / 3216 500

http://www.hta-bi.bfh.ch/E/energietechnik **Email :** valentin.crastan@bluewin.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme in Photovoltaic Energy Conversion

ANNUAL REPORT 2000

Project Number: 29909
Contract Number: 69804

Project Title: **SOLRIF (Solar Roof Integration Frame)**

Abstract:

Building integration technologies for photovoltaic systems are, beside cell & module improvements, one of the most important aspects to reduce the price of solar electricity. But beside costs, there are other relevant requirements such as the architectural and esthetical appearance of the building itself.
SOLRIF is a new photovoltaic (PV) system for inclined roofs, which meets the aspects described above. Combined with any solar panel SOLRIF forms a sealed roofing layer, like standard roofs with tiles, while generating electricity at the same time and offering a sustainable solution without greenhouse gases at zero operating costs. This new system is suitable for almost any type of inclined roofs in existing or new buildings and meets high esthetical demands too. The innovative design is optimised in view of economical, ecological and functional aspects. The SOLRIF system consists of any type of PV laminate and four specially designed aluminium profiles, which replace the conventional framing of standard PV laminates. SOLRIF is independent of the size and makes of the PV laminates and is therefore suited to different products.

During the two years project time 6 installations with a total amount of over 100 kW nominal power have been realised in Switzerland. Further approx. 150 kWp have been installed in Germany since beginning 2000. In advance two test installations, one in Switzerland and one in the Netherlands were built. Collaboration has been established between Enecolo and ECN (The Netherlands Energy Research Foundation). Main goal was the further improvement of the system, the test under severe weather conditions and approval testing. Several tests were done with both test installations in order to gain experiences at different locations. Further testing was done in another test installation at ISPRA. Target was to implement the product in the certification process (IEC, CE marking, etc.).
Some improvement could be incorporated. Special attention was given to standard solutions for roofing edges in connection with other roofing materials and on the profiles to reduce the material. In parallel negotiations were taking place with module manufacturers about production and introduction of SOLRIF in their manufacturing line.

The experiences with the installation and operation of SOLRIF- elements are very positive. The system has proofed its excellent performance in all relevant terms such as aesthetics, mounting speed, roofing function, flexibility and cost effectiveness.

Duration of the Project: Dec. 1st 1998- Dec. 15th 2000

Responsible for the project : Peter Toggweiler

Reporting on the Project: Daniel Ruoss

Address: Enecolo AG
Lindhofstr. 52
8617 Mönchaltorf

Telephone: 01 / 994 90 01 **Fax:** 01 / 994 90 05

http://www.solarstrom.ch **Email:** info@enecolo.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number : 28023
Contract Number : 68221

Project Title : **PV-insulation-modules**

Abstract :

In the project PV-insulation-modules different insulation materials and products have been investigated concerning the possibilities to combine them with photovoltaics.
About 12 interesting variants of combination have been found. They were investigated and judged according to several requirements, that result out of norms of the building sector and from environmental influences.
The judgement shows the forces and weaknesses of each variant. Some variants are very promising. Several meetings with responsible peoples from the insulation industry showed as well their interest in combined elements. Together with them, further investigations have to be done, and new products will follow.

Duration of the Project : Winter 1998/99 until Summer 2000

Responsible for the project : ZAGSOLAR

Reporting on the project : Richard Durot

Address : ZAGSOLAR
Amlehnstr. 33
6010 Kriens

Telephone : 041 312 09 40 **Fax :** 041 312 09 41
http : **E-mail :** r.durot@tic.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number : 27703
Contract Number : 69120

Project Title :	New Light-Weight Flat Roof Photovoltaic Module Mounting System Especially for Use on Roofs with Extreme Low Static Structure Reserves

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 labor 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 time hardly allow any additional weight on them.

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

The main goal of the project was to find a way of incorporating the weight of the already-there gravel into a holding structure for PV-modules. At the same time, this PV-module holding structure itself should have almost no weight, so the additional weight brought onto the roof would remain minimal.

It was found, that some technical approaches not yet investigate are possible. As a last step in the project, some prototypes will be tested for verification purposes.

Duration of the Project :	January 1999 - March 2001

Responsible for the project : Christian Meier

Reporting on the project : Christian Meier, Roland Frei

Address : energiebüro
Limmatstrasse 230
CH-8005 Zürich/Switzerland

Telephone : ++ 41 1 242 80 60

Fax : ++ 41 1 242 80 86

Internet-Hompage http://www.energieburo.ch

Email : info@energieburo.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : 32 443
Contract Number : 72 340

Project Title : **LonWorks as Fieldbus for PV-Installations**

Abstract :

The growing market for photovoltaics increasingly requires suitable quality controls covering plant operators, planners and installers, as well as the electric utilities. Additionally, the interest of the general public in the behaviour of PV plants is growing. This includes information from everyday practice. Alongside data retrieval, other themes such as the operative management of the unit and energy management become increasingly important for grid connected PV systems. Todays measuring systems are not compatible with each other. Data communication between different PV plants with computer aided analysis- and visualisation programmes is very complicated.

The goal of this project is to introduce the very popular LonWorks-technology as a new standard for PV-applications. The first objective is to develop a LonWorks-interface for our Convert inverters and to connect them into a small network.

LonWorks was introduced by Motorola and Toshiba in 1991. Today it leads the world market for field bus systems. With plug&play, components by several manufacturers can easily be incorporated into a LonWorks network.Today more than 3‘500 companies use LonWorks technology.

Duration of the Project : 01.06.99 – 31.01.01

Responsible for the project : Christoph von Bergen

Reporting on the project : Marco Rotellini, Ch. von Bergen

Address : Sputnik Engineering AG
Hauptstrasse 135
CH-2560 Nidau

Telephone : 032 332 20 60 **Fax :** 032 332 20 69

http://www.solarmax.com **E-mail :** sputnik@solarmax.com

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme in Photovoltaic Energy Conversion

ANNUAL REPORT 2000

Project Number : 32 991
Contract Number : 72 909

Project Title : **SOLMAX, flat roof mounting system made of recycling material**

Abstract : The photovoltaic industry progressed impressively in recent years. The market is constantly growing stronger. Production capacity is increasing every day. In this context, building integration will become a major market segment. Flat roofs are already and will continue to be a non negligible part of it. Thanks to the Solmax system, the cost of the mounting can be drastically compressed (between 0.3 and 0.6 Euro/Watt). Cost-effectiveness of photovoltaic systems is thus considerably improved.

Solmax represents the recent evolution of container-based mounting systems. It keeps the advantages of its predecessors and brings new interesting features:

- it is made of black recycling polyethylene and therefore extremely light
- its flexibility allows mounting modules with a length of between 115 and 150 cm with the same standard base
- modules are mounted vertically. Up to three big modules (110 - 120 W) or up to four (80-90 W) can be installed with one Solmax. This corresponds to up to 360 W
- final price offers excellent performance-cost ratio.

Duration of the project : 1st of June 1999 – 30th of March 2000

Responsible for the Project : J. Bonvin
Reporting on the project : J. Bonvin

Address : Solstis Sàrl, rue du Lac 10, CH-1207 Genève

Telephone : ++41 22 786 37 00 **Fax :** ++41 22 786 63 80

http://www.solstis.ch **E-Mail :** info@solstis.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme in Photovoltaic Energy Conversion

ANNUAL REPORT 2000

Project Number: 37527
Contract Number: 77266

Project Title: **SOLGREEN- Optimierung des Systems Solgreen**

Abstract:

SOLGREEN is a new mounting structure especially developed for green roofs. The demand is to develop a light- weight system, which adds almost no weight to the green roof and uses the existing substrate on the roof to withstand the wind forces. Thus the structure is fixed by the gravel foundation of the roof and the substrate for the roof vegetation. Thanks to this approach a new, material saving, aesthetically pleasing and light- weight mounting structure can be realised for the solar array.

An important design issue is to give a maximum level over ground as possible, because of the ground vegetation up to 40 cm and the involved roof maintenance for a green roof, e.g. grass mowing. These features result in an interesting new and elegant design for flat roofs. The drawback is higher cost due to the design (because of the space above ground) and the used materials. The products on the market (SOLGREEN large and small) have to be optimised in view of cost otherwise such systems will have a niche market character. The project team Enecolo AG, Solstis Sàrl, Ernst Schweizer AG and EPFL- LESO will develop new solutions for green roofs and will also come up with a cost competitive product on the market.

The existing SOLGREEN system is available in two versions (large and small) and has an inclination angle of 20- 30°. The products were applied in three PV installation (one for solar stock exchanges and two as pilot- and demonstration project in Chur and in Lausanne (DEMOSITE). One installation with 11 kWp installed capacity is located in Chur and operated by the company J. Gasser Baumaterialien AG. The company received the Solarpreis 2000 for the new building, which indicates a new building generation for the 21st century. A further installation (18 kWp) was concluded for the IWB solar stock exchange on a school- house in Basel- Wasgenring.

New systems will be constructed and tested at the EPFL- LESO or at Enecolo AG in Mönchaltorf. So far several new concepts have been developed and will be further evaluated and tested. One system comes from Solstis Sàrl and uses mainly Deltatec® plats, another concept has been proposed by Enecolo AG in co-operation with Ernst Schweizer AG. Both systems will go into further development progress and with the better concept an installation of approx. 20 kWp is planned in Zurich for 2001.

Duration of the Project: April 1st 2000- November 30th 2001

Responsible for the project: Peter Toggweiler
Reporting on the Project: Daniel Ruoss, Peter Toggweiler
Address: Enecolo AG
Lindhofstr. 52
8617 Mönchaltorf

Telephone: 01 / 994 90 01 **Fax:** 01 / 994 90 05
http://www.solarstrom.ch **Email**: info@enecolo.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number : 37528
Contract Number : 77267

Project Title : **Solardachschiefer SUNPLICITY**

Abstract : SUNPLICITY is being developed as a new solar building element for tilted roofs which fits in every conventional roof built from fibre cement shingles, being widely used in northern Europe. Its dimensions are exactly identical to a conventional tile, not only both in length and width, but also in thickness. The new solar roof shingle is absolutely plane and flat, as is a normal fibre cement shingle. The integration into existing roofs is therefore straightforward: wherever the roofer wants solar shingles, he replaces conventional tiles with the new solar tile. Even the electrical connections are in the same plane. The integrated connecting cable eliminates the roofer's design and installation obstacles and permits the roofer to do the electrician's job also.

Shingles on sloped roofs have a large area of overlap. In fact, the overlap is more than 2,16. The unique polymer used in this design allows the tempered glass to be the structural substrate for the entire shingle while protecting the glass in this large overlap region. Cost and market acceptance influenced the design size of the solar shingle. Several sizes of conventional shingles are used in the market, but the most common ones are 40*60 cm. However, in order to become more competitive with clay tiles, somewhat larger shingles of 40*72 cm are used for almost all new roofs. This larger size was selected for SUNPLICITY because larger size reduces production cost and the larger conventional shingle is gaining in market penetration. While even larger shingles would further reduce fabrication cost, this would likely be more than offset by higher installation costs due to special instruction, handling and mounting procedures for any non-standard sizes.

The mechanical layout had been tested during several mounting trials, which were conducted under the auspices of several professional roofers. The design for the interconnecting cabling system is complete. Manufacturing of larger prototype area is underway, to be tested in 2001.

Duration of the Project : 1.4.2000 – 30.11.2001

Responsible for the project : Markus Real

Reporting on the project : Markus Real

Address : Alpha Real AG,
Feldeggstrasse 89, 8008 Zürich

Telephone : +41 1 383 02 08 **Fax :** +41 1 383 18 95

http:// **Email :** alphareal@access.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : 14'556
Contract Number : 54'108

Project Title :	**Système hybride simple PV/T 7kW$_p$ à Domdidier au Centre d'Entretien autoroutier de la N1 (PV/T = système hybride simple Photovoltaïque / Thermique)**

Abstract :

Simple Hybrid System (PV/T) 7 kW$_p$ at N1 Motorway Maintenance Center, Domdidier/FR (PV/T = simple hybrid system Photovoltaic / Thermic

The project of the system PV/T 7 kW$_p$ consist to put on a strip of the building a set of cells photovoltaics. It is constitued of 33 simple windows panels and each carry 144 photovoltaics cells ASE Alzenau, as a replacement for the normal garage's windows shed of the "Motorway Maintenance Center" at Domdidier/FR. The installation's power is 6'700 W$_p$.

The heat produced by the PV elements is recuperated by 2 ventilators, which blow the warm air down (on the garage's floor) in order to avoid the frost of the hall during winter. When the temperature is too high, the warm air is directly expelled outside of the building. That is simple hybrid system PV/T.

Duration of the Project :	October 1995 to June 2001

Responsible for the project : Mr Jacques Audergon

Reporting on the project : Mr Jacques Audergon

Address : GEIMESA au nom du BARF
Av. du Midi 13
1700 FRIBOURG

Telephone : + 41 (0) 26 425 85 30 **Fax : +** 41 (0) 26 425 85 39

http://www.geimesa.ch **E-mail :** geimesa@geimesa.mcnet.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : 17862
Contract Number : 57447

Project Title : **Roof integrated amorphous silicon photovoltaic plant IMT Neuchâtel**

Abstract :

The grid-connected PV plant of 6.4 kWp at IMT Neuchatel was the first of its kind in Switzerland: large-area amorphous silicon panels are aestethically integrated into the roof of a sixty years old building. The plant was implemented and commissioned in autumn 1996. During the four years of operation the plant showed an excellent reliability and performance:

- availability since the start-up of 100 %,
- cummulated energy production of 26.6 MWh,
- annual production yield around 1'000 kWh/kWp,
- coefficient of performance of 0.76,
- no further noticable reduction of power production has been observed after the initial light induced degradation (Staebler-Wronski effect) during the first year of operation.

These figures are remarkably high for a plant located on the Swiss Plateau. Moreover, during the summer period the panels operate at relatively high temperatures resulting from the roof integration without backside ventilation. Amorphous silicon modules have, thus, proven to be particularly suitable for building integration. At higher operation temperatures amorphous silicon modules show production yields that are 15 to 20 % superior to those of crystalline silicon modules of identical nominal power rating.

Duration of the Project : 01.08.1996 – 31.12.2000

Responsible for the project : Reto Tscharner

Reporting on the project : Reto Tscharner

Address : Institut de Microtechnique
Rue A.-L. Breguet 2
CH-2000 Neuchâtel

Telephone : +41 32 718 33 55 **Fax :** +41 32 718 32 01

http://www-micromorph.unine.ch **Email :** reto.tscharner@unine.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number : 20735
Contract Number : 60338

Project Title : **PV-roof integration with module integrated inverters**

Abstract :

In spring 1995 a new farm with an additional living house for the family Zaugg was built. Due to the favourable exposition the south roof offered good conditions for the use of active solar systems.

The newly with PV-shingles covered roof section, was previous covered with tiles. The heat collected under the tiles was used for the hay ventilation. With the installation of the hybrid PV-thermal system the efficiency of the heating increased considerably resulting in reduced working periods of the ventilation system. For this project PV-modules with integrated micro-inverters have been used.

Three technological attributes are associated with this project: roof integrated PV system, PV-thermal hybrid system and the module-integrated inverter. It is the goal of the project to gain practical experience (electrical and thermal characteristics) of the micro-inverter in the special operating conditions of a roof-integrated, PV-thermal hybrid system.

Duration of the Project : 01.06.97 – 30.04.00

Responsible for the project : B. Stucki

Reporting on the project : A. Eckmanns

Address : Atlantis Energie AG
Lindenrain 4
3012 Bern

Telephone : +41-31 300 30 20 **Fax :** +41-31 300 30 30

http://www.atlantisenergy.ch **E-mail :** info@atlantisenergy.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme in Photovoltaic Energy Conversion

ANNUAL REPORT 2000

Project Number : 29910
Contract Number : 69805

Project Title : Stand-alone hybrid (PV-Diesel) installation with 3,1 kW_p PV-roof integrated solar slates (Sunslates^{TM}) in Soyhières (JU)

Abstract :

Technical study, installation, implementation, measurement-campaign, data publication of a hybrid (PV-Diesel) power system wholly autonomous (2 km distance to the existing electrical grid). This project proposes an innovative solution (of Swiss conception) for PV architectural integration.

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

The measurement campaign has started with an Atlantis mobile system in December 1999 and is going to last one year. The first results are going to be available in spring 2001.

The installation was used as example and local experience for the participation of Switzerland in IEA PVPS Task III.

Duration of the Project : December 1998 - March 2002

Responsible for the project: Bernard Bezençon

Reporting on the project: Bernard Bezençon

Address: Atlantis Solar Systems Ltd
Lindenrain 4
CH - 3012 Bern

Phone: +41 (0)31 300 32 20
http://www.atlantisenergy.com

Fax: +41 (0)31 300 32 10
E-mail: info@atlantisenergy.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : 32403
Contract Number : 72280

Project Title : **4.8 kWp P&D- Anlage SOLRIF, Lindenmatt**

Abstract :

During 1999 Enecolo has renovated an eleven years old installation with 5.6 kW nominal power with standard modules based on crystalline cells. The frames of the modules were replaced by SOLRIF in order to improve the roof integration and to reduce the soiling at the lower edge profile.

The measured power degradation is around 8 %. The change of U-I – curve compared to the data sheet has to be considered while sizing the inverter input range. The results indicate a lower voltage compared to the given values by the supplier. Further more it was noticed that the inverter (ASP Top Class) is not able to use the specified voltage window. These circumstances cause significant production losses during the summer months.

The new roof integration system has proven all the expected advantages. The mounting goes fast, it looks attractive, the inactive roof area is very low, edge soiling is not any more a problem, the snow gliding is improved and rain tightness is as expected. During the 12 month period from 9/99 to 9/00 here were two have storms with strong rain were some water entered through the roof as it happened with clay tile roofs as well. It is recommended to install a second roof layer as usually done in conventional roofing technology. There is no second roof layer installed at the Lindenmatt site.

Duration of the Project : 01. Juni 1999- 01. September 2000

Responsible for the Project: Enecolo AG

Reporting on the Project: Peter Toggweiler

Address: Enecolo AG
Lindhofstr. 52
8617 Mönchaltorf

Telephone: 01 / 994 90 01 **Fax:** 01 / 994 90 05

http://www.solarstrom.ch **E-mail**: info@enecolo.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number: 33046
Contract Number: 73003

Project Title: **PV roofs in the old town of Unterseen**

Abstract:
Unterseen, a part of the city of Interlaken, located on the river Aare between the two lakes of Thun and Brienz, has a historical centre, which is marked by an old town house and other historical monuments. The integration of photovoltaic modules into the roof of a newly designed building in an old town, taking historical aspects into account, represented a special challenge in terms of a combination of modern technology and a traditional townscape. A clever module design and lot of convincing was necessary in order to have the photovoltaic project approved by the local townscape authority, the cantonal as well as the national preservation of historical monuments.
The installed power is 6 kWp and the energy production so far meets the expected output. The results of the monitoring campaign, which runs until summer 2001, will be available as a final report towards the end of year 2001.

Duration of the Project: 1997 - 2001

Responsible for the project: Fritz Bigler / René Hofer

Reporting on the project: Fritz Bigler

Address :
Industrielle Betriebe Interlaken IBI
Fabrikstrasse 8
Postfach 536
3800 Interlaken

Telephone : 033 826 30 00
Fax : 033 826 30 10
http://www.ibi-interlaken.ch
Email : fritz.bigler@ibi-interlaken.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : 35715
Contract Number : 75454

Project Title : **Slopedroof- and façade – mounting-system AluTec / AluVer**

Abstract :

The AluTec-mounting system was developed firstable for mounting framed PV-modules onto existing sloped roofs and at façades.
Main features of system are: Modules mounting without use of any tools
Very fast and thus cost effective mounting capability
Changeability of every module of the plant for maintenance and repair.
The plant situated on two parts of roof and a peak power of 32,56 kWp was realised in March / April 2000 and is producing electric energy into grid of the electric company Hünenberg (EGH) since 19st of April 2000. For the placement of the 296 module a team of three skilled workers were engaged only one day.
Until now the expectations for the mounting system have been fulfilled thus the stability against wind has been proofed at a peak wind force of 85 km per hours. Moore experiences with stronger wind have been done at new system installations nearby the coast of netherlands.
Till now, no special soil deposition caused by the mounting system has to been observed.

Interested visitors may inform themselves at any time about the state of the plant as well as energy production by the user guided touch screen terminal at the wall nearby the footpath.
The predicted energy production of 25'100 kWh per year seems still to be attainable after the experiences of the first eight and a half month and a production of 19'118 kWh during this time.

Duration of the Project : December 1999 until June 2001

Responsible for the project : Urs Bühler

Reporting on the project : Urs Bühler

Address : Urs Bühler Energy Systems and Engineering
Seemattstrasse 21 B, CH-6330 Cham

Telephone : 041 / 780 07 36 **Fax :** 041 / 780 07 36

http:// **Email :** u.bue_cham@bluewin.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number: 37526
Contract Number: 77265

Project Title: **PV Eurodach amorph**

Abstract:

EURODACH is the effective combination of a folded metal roof and full-area thermal insulation with stone wool. The combination with PV solar elements is a new development of FLUMROC Inc. and SCHNEIDER mounting systems.

The goals of this project are to get a multifunctional roof as weather protection, thermal insulation, and electricity production, to get experience with the mecanically connected materials having different temperature coefficients, and to learn about the energy yield of the PV installation with amorphuous triple cell modules.

The development of the system is now going on to optimize the module sizes, the fastening of the modules on the roof, and to reduce shadowing due to the folds of the roof.

Duration of the Project: July 1999 - December 2001

Responsible for the project: Hugo Kessler

Reporting on the project: Raimund Hächler

Address: PAMAG Engineering
Industriestrasse 8
8890 Flums

Telephone: 081 734 1511 **Fax:** 081 734 1506

http://www.flumroc.ch **Email:** hke.pamag@flumroc.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : 37546
Contract Number : 77283

Project Title : **10 Roof Integrated PV Small Scale Systems**

Abstract :
Roof integrated small scale PV systems were recognised as an upcoming market niche. Such installations had a very promising response in the Netherlands [1]. The use of an adapted roof integration system designed for thermal collectors enables detached but visually combined PV/thermal installation.
The proposed and evaluated small scale PV system has a modular design. Each PV module consists of a large area PV laminate (2.3 m^2) and a dedicated DC/AC converter with 240 W maximum power output.
Besides the PV laminate the proposed system uses commercially available components. All used components are ready made for plug-and-play installation by non-electricians. The system is promoted as a package in combination with a standardised solar thermal hot water system for single family houses. Options with one and two PV units are available for installers as fixed price products.
Critical aspects of such complete systems are ease of installation and total cost of ownership. The focus of this project is therefor on system aspects, like

- Installation with electrical plug-and-play concept
- Collaboration between the solar workman and the electrician
- Involvement of the home owner
- Average performance and reliability
- Total system cost

During the first month of the project the aim was to sell and install 10 systems and to set up the performance monitoring scheme. Unfortunately, market response was low and only three systems were sold in 2000.

Duration of the Project : May 2000 - May 2002

Responsible for the project : Andreas Haller

Reporting on the project : Andreas Haller

Address : Ernst Schweizer AG, CH-8908 Hedingen

Telephone : +41 1 763 63 80 **Fax :** +41 1 763 63 18

http://www.schweizer-metallbau.ch **Email :** andreas.haller@schweizer-metallbau.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number : 23703
Contract Number : 68140

Project Title : **Pilot installation 10kWp Flat Roof System "SOLGREEN"**

Abstract :

Green flat roofs as water retension reservoirs usually do not allow to install PV on the same place. The SolGreen flat roof mounting system has been developed by LESO-EPFL in co-operation with Enecolo AG.

In April 2000 the pilot installation had been erected on the roof of the storage hall of Josias Gasser Baumaterialien AG at Chur. The light-weight construction elements caused low transport costs.

The development of the system is now going on to reduce the material costs. A measurement equipment has been installed, but there are still no results available.

Duration of the Project : October 1998 - October 2001

Responsible for the project : Raimund Hächler

Reporting on the project : Raimund Hächler

Address : ars solaris hächler
Masanserstr. 62
7000 Chur

Telephone : 081 353 3223 **Fax :** 081 353 3213

http:// **Email :** ars_solaris@freesurf.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number: 17225
Contract Number: 59391

Project Title: **Three pilot 10 kWp integrated PV sound barrier fields**

Abstract:

After an ideas competition in 1996, six companies where given the the opportunity to construct a prototype of their newly developped integrated PV-soundbarrier concepts. The main goal was to develop highly integrated concepts, allowing the reduction of PV sounbarrier systems costs, as well as the demonstration of specific concepts for different noise situations.

The project is strongly correlated with a german project. Three of the concepts of the competition are demonstrated along a highway near Munich, constructed in 1997. The three swiss installations had to be constructed at different locations, reflecting three typical situations for soundbarriers.

The first Swiss installation was the worlds first Bifacial PV-Soundbarrier. It was built on the highway bridge at Wallisellen-Aubrugg in 1997. The operational experience of the installation is positive. But due to the different efficiencies of the two cell sides, its specific yield lies somewhat behind a conventional PV installation.

The second swiss plant was finished in automn 1998. The zig-zag construction is situated along the railway line in Wallisellen in a densly habited area with some local shadowing. Its performance and its specific yield is comparatively low due to a combination of several reasons (geometry of the concept, inverter, high module temperature, local shadows).

The 3rd installation was constructed along the A1 at Brüttisellen in 1999. Its vertical panels are equiped with amorphous modules. First findings show, that the performance of the systems is quite high, but the mechanical construction has to be improved strongly. A small trial field with cells directly laminated onto the steel panel, also installed at Brüttisellen, could be the key development for this concept.

This project was financed by the Swiss Federal Office of Energy, the Swiss Federal Office of Motorways and the special electricity saving fund by the city of Zurich (EWZ).

Duration of the Project: 1 January 1997 to 31 Dec 2001

Responsible for the Project: TNC Consulting AG
Reporting on the Project: Th. Nordmann, A. Frölich
Address: Seestrasse 141, CH - 8703 Erlenbach
Telephone: 01 / 991 55 77 **Fax:** 01 / 991 55 87
http://www.tnc.ch **E-Mail:** nordmann@tnc.ch, froelich@tnc.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number : 37146
Contract Number : 76903

Project Title : **PV / Noise Barrier Installation "Alpha A1" in Safenwil, Switzerland**

Abstract : First report on a combined PV / Noise Barrier installation with a capacity of 80 kWp which has been installed in Safenwil on the motorway Zürich – Berne. The Installation is the first privately owned PV power installation on a motorway noise barrier in Switzerland. The project was initiated by IG SOLAR Safenwil, a local co-operative for the promotion of solar energy.
The installation will be operated by the Ekotech AG company, whose shares are held by IG SOLAR and a (growing) number of private persons. The power produced is being sold to persons and institutions interested in buying "green" power.
The installation fulfils the following aims:

- Demonstration of a fast and modular technology which can also easily be implemented elsewhere (370 metres of 4-metre long, prefabricated sections were installed in just 2,5 days by three persons; the complete DC and AC electrical installation of 24 Inverters was carried out in 8,5 days by three persons)
- Demonstration of the possibilities of private funding for PV plant.
- Promotion of the idea of PV energy production in the general public (thousands drive past the installation every day, data will be presented on the internet)
- Comparison of energy production with that of similar installations with different climatic conditions

Duration of the Project : 2000 – 2002

Responsible for the project : Ruedi Hottiger-Reck

Reporting on the project : Ruedi Hottiger-Reck

Address : IG SOLAR Safenwil
Höliweg 3 / Postfach
5745 Safenwil

Telephone :+41 (0) 62 797 70 05 **Fax :** +41 (0) 62 798 00 15

http://www.ekotech.ch **E-mail :** info@ekotech.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number: 97.0205 (BBW) EU Contract number: SE/00068/97/NL/DE/CH

Large scale integration of AC PV modules into a noise barrier along a highway near Amsterdam (PVNB 220)

Introduction

The 220 kWp Grid Connected PV Plant along the A9 highway near Amsterdam went into operation at the end of 1998. The plant features 2160 PV modules, each with an integrated DC/AC microinverter. All the AC-modules are fully integrated into a purpose built noise barrier over a length of 1650 meters.

The aim of this project is:

Reduction of system costs on an overall level through volume, integrated design and prefabrication. -Evaluation of technical, architectural and economical aspects. -Investigation of performance and impact on utility grid of a large number of parallel AC-modules.

This final report of the project looks at:

- maintenance - performance - final costs - comparison to other motorway projects

This demonstration project was supported by the European Commission, DG XVII, Thermie-A-Projects, Contract number SE/00068/97/NL/DE/CH and the Netherlands Agency for Energy and Environment (NOVEM).

The partners for the project where:

NOUON International / Renewable Energy (coordinator and owner),

Netherlands Energy Research Foundation (ECN),

TNC Energie Consulting GmbH, Freiburg, and TNC Consulting AG, Erlenbach,

Fraunhofer Institut für Solare Energiesysteme.

The main subcontractor was Shell Solar Energy for the supply and installation of the entire PV system.

Duration of the project:	June 1998 to July 2001

Responsible for the Project:	TNC Consulting AG
Reporting on the Project:	Th. Nordman, L. Clavadetscher
Address:	Seestrasse 141, CH - 8703 Erlenbach
Telephone:	01 - 991 55 77 Fax: 01 - 991 55 78
E-Mail:	nordmann@tnc.ch, clavadetscher@tnc.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number: 97.0205 (BBW) EU Contract number: SE/00068/97/NL/DE/CH

Large scale integration of AC PV modules into a noise barrier along a highway near Amsterdam (PVNB 220)

Introduction

The 220 kWp Grid Connected PV Plant along the A9 highway near Amsterdam went into operation at the end of 1998. The plant features 2160 PV modules, each with an integrated DC/AC microinverter. All the AC-modules are fully integrated into a purpose built noise barrier over a length of 1650 meters.

The aim of this project is:

Reduction of system costs on an overall level through volume, integrated design and prefabrication. -Evaluation of technical, architectural and economical aspects. -Investigation of performance and impact on utility grid of a large number of parallel AC-modules.

This final report of the project looks at:

- maintenance - performance - final costs - comparison to other motorway projects

This demonstration project was supported by the European Commission, DG XVII, Thermie-A-Projects, Contract number SE/00068/97/NL/DE/CH and the Netherlands Agency for Energy and Environment (NOVEM).

The partners for the project where:

NOUON International / Renewable Energy (coordinator and owner),

Netherlands Energy Research Foundation (ECN),

TNC Energie Consulting GmbH, Freiburg, and TNC Consulting AG, Erlenbach,

Fraunhofer Institut für Solare Energiesysteme.

The main subcontractor was Shell Solar Energy for the supply and installation of the entire PV system.

Duration of the project:	June 1998 to July 2001

Responsible for the Project:	TNC Consulting AG
Reporting on the Project:	Th. Nordman, L. Clavadetscher
Address:	Seestrasse 141, CH - 8703 Erlenbach
Telephone:	01 - 991 55 77 Fax: 01 - 991 55 78
E-Mail:	nordmann@tnc.ch, clavadetscher@tnc.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number: 32404
Contract Number: 72281

Project Title: **SOLARSAIL Münsingen**

Abstract:

The Solarsail in Münsingen, between Bern and Thun is a solar art project and one of the most spectacular solar power plants in the world. The sail is 22 meters high with a surface of 90 m^2. The aim was to build an extraordinary plant to show people the beauties of solar energy.

Starting in the psychiatric center of Münsingen the project got the support of the community of Münsingen. The canton of Bern and the Swiss federal office of energy were also persuaded to support the project. Additionally three big Swiss companies and more than 30 private persons support the project financially. The opening ceremony took place on August 15th. Since then the power plant works perfectly.

You have to visit the Solarsail to get the right impression – when you stand in front of it you realise how big it is. Take your time to see how the colors of the PV-panels change during the day. And when the sun sets you can see the deep blue panels against the evening sky. It's a quiet place – the Solarsail place. And while you are admiring the architecture you have a lot of time to the read the well designed information board and to follow the electronic display. You probably also have time to think about our energy consumption and the beautiful alternatives we do have today.

Wouldn't it be a nicer world with a billion Solarsails producing our energy? Without noise, without pollution, without risk.

Visit the Solarsail and tell us what you think about it.
You might agree with one of our friends who said: "It's just gorgeous!"

Duration of the Project: March 1999 - September 2000

Responsible for the project: Verein Sonnensegel

Reporting on the project: Stephan Kormann

Address: Verein Sonnensegel, 3110 Münsingen
Secretary of the Verein:
Stephan Kormann, Bürenstrasse 45, 3007 Bern

Telephone: ++41 31 720 83 05 **Fax:** ++41 31 720 88 00

http://www.solarsail.ch **E-mail:**solarsail@gmx.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : 32405
Contract Number : 72282

Project Title :	**Amburnex Solar Farm (3 kWp)**

Abstract :

This project could not be finished in 2000 as initially planned, mainly due to lack of human resources and delays in PV panels delivery.

However, the mobile van equipped with batteries, inverter, charger and control unit has been fully tested over a short period of 3 weeks. The batteries were then loaded by a small portable generator operated by the control unit.

In 2001, it is planned to build a shelter for this mobile van, the roof of which will be made of PV panels.

Duration of the Project :	1st April 1999 – 15 December 2002

Responsible for the project : FAVRE Pascal

Reporting on the project : FAVRE Pascal

Address : Service Energie SIL
Route de Genève 52
1004 Lausanne

Telephone : 021/315.87.12 **Fax :** 021/315.80.15

http://www.lausanne.ch/energie **Email :** pierre-pascal.favre@lausanne.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number: 32'990
Contract Number: 72'908

Project Title: 27 kWp PV-Installation High School Zurich-Stadelhofen - Plant Monitoring

Abstract:

When the gymnasium hall of the high school Stadelhofen in the city of Zurich was renovated and rebuilt, a pv installation was integrated into the roof and the facade. The project was one of the winners of the Swiss solar prize in 1999,for the best integrated architectural design and the use of pv modules as multifunctional elements. The solar cells are integrated into the specially manufactured double glazed highly insulating roof windows. These roof modules have a nominal capacity of 13.7 kWp. On the south/ west facade of the building special laminated solar modules with a total capacity of 12.8 kWp serve as a shading device for the building.

Measurements of the electric output power of randomly selected single modules in independent laboratories have shown a difference between the nominal contracted and the delivered power of the modules. The delivered power is 23.5 kWp, that is 11.3%less then designed. The module price had to be adjusted and the expected annual yield had to be reduced from 18'500 kWh to 16'360 kWh.

The installation started operation in July 1999.In 2000 the one-year measuring campaign was continued and completed. In the total period the installation produced 16'070 kWh, or 683 kWh/kWp, based on the adjusted (measured)nominal power of the modules. The cell temperatures showed high values in summer of up to 85.4 °C and a yearly weighted average temperature of 52.9 °C. This is considerably more

than in a well ventilated installation, causing an additional loss of about 7 %of the yield. Despite of this, the installation operated very well in the first year. There was one interruption of 12 days, when the plant stopped after a grid fault and no trained operator was there.

The self-cleaning capability of the little sloped roof was of some concern, as the dirt is not washed away by the rain. This effect was not observed up to know.

This project was financed by the state of Zurich, the Swiss Federal Office of Energy and the special electricity saving fond by the city of Zurich (EWZ).The data acquisition campaign is fully financed by the Swiss Federal Office of Energy.

Duration of the Project: April 1999 to February 2001 (measuring programme)

Responsible for the project: Th.Nordmann
Reporting on the project: M.Dürr, A.Frölich, Th.Nordmann
Address: TNC Consulting AG
Seestrasse 141
8703 Erlenbach

Telephone: 01 / 991 55 77 **Fax:** 01 / 991 55 87
http:// www.tnc.ch **Email:** mail@tnc.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : 33643
Contract Number : 73545

Project Title : **PV-installation penal institution Wauwilermoos**

Abstract :

In October 1999 the 13.2 kW-PV-installation at the panel institution Wauwilermoos at Egolzwil went to operation. Until now, it is running without interruption.
In the first year there was an energy-production of 11186 kWh which is 5 % more than expected due to a high irradiation.
The good operation of the PV-installation can be controlled by the well-situated freestandig information-board where many people pass and by the data-acquisition-system.

Duration of the Project : October 1999 until October 2000

Responsible for the project : ZAGSOLAR

Reporting on the project : Richard Durot

Address : ZAGSOLAR
Amlehnstr. 33
6010 Kriens

Telephone : 041 312 09 40
http :

Fax : 041 312 09 41
E-mail : r.durot@tic.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : 36407
Contract Number : 77803

Project Title : SolarCat - Solar-Electric powered Passenger Ship

Abstract :

The project SolarCat includes engineering design, construction and operation of a solar-electric powered passenger ship for inland waterways. The ship is a catamaran type vessel with a length of 33 m and a width of 11 m. It is powered by two 71 kW frequency-controlled electric motors. The electric energy is produced by 20 kWp of photovoltaic panels and stored in two batteries of 480 V and 240 Ah each. With a passenger capacity of 200 persons the project will be the largest solar-powered ship worldwide.

The ship is at present under construction. Large parts of the hulls are already completed and the final assembling will take place in January, 2001 in Biel/Bienne. The first test runs are scheduled for May/June 2001.

The project is financed largely by sponsors, mainly by the insurance company Schweizerische Mobiliar and the watch company Certina. For this reason the name of the project had been changed recently from SolarCat to MobiCat. In addition to the main sponsors the project is supported by electric utilities and other private companies. The remaining costs are borne by the navigation company of the Lake of Biel/Bienne, BSG, the owner and operator of the ship. The Federal Office of Energy is co-funding the project as a pilot and demonstration activity.

The ultimate goal of the project is to demonstrate the feasibility of large solar-powered passenger ships and to present new soltutions towards sustainable mobility on inland waterways.

Duration of the Project : June 2000 - December 2002

Responsible for the project: Dr. Rudolf Minder
Reporting on the project: Dr. Rudolf Minder
Address: Minder Energy Consulting
Ruchweid 22, CH-8917 Oberlunkhofen
Telephone: +41 56 640 14 64 **Fax:** +41 56 640 14 62
http://www.minder-energy.ch **E-mail:** rudolf.minder@bluewin.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : BBW 97.0393-1
Contract Number : OFES No. 97.0393-1

Project Title : **151 small grid connected PV stations for a total of 200kWp, of which 30 kWp in Switzerland**

Abstract :

The general objective of the project is the conception of small grid connected PV stations with a total power of 200 kWp, of which 30 kWp in Switzerland

The objective is an application of integrated module solution. This solution consists in the realisation of many roofs with waterproof PV modules instead of tiles. 10.7 kWp were installed in this way in 1999, and 20.6 kWp in 2000, completing the Swiss program part.
Small PV plant are installed by private individuals and companies. This small PV plants can be done by the customer himself. Their peak power range from 1,08 to 11,52KWp.

Also, we have implemented monitoring systems on some of these installations, and widely used PVSYST software for production forecast.

In 2000, we also went on with diffusing information about our project toward a large public.

Duration of the Project : 1997 - 2001

Responsible for the project : PHEBUS SUISSE
Co-proposant: SUNWATT BIO ENERGIE SA

Reporting on the project : Phébus suisse, Sunwatt Bio Energie SA.

Address : Phébus suisse
Case postale 305; CH-1225 Chêne-Bourg

Telephone : +41 22 348 73 66 **Fax** : +41 22 348 73 53

Email : phebus.suisse@swissonline.ch
Schneider-m@bluewin.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : Partie Genève: BBW 96.03.44-1
Partie Lausanne: BBW 96.03.44-2
Contract Number : OFES No. 96.0344 – 1 et 2

Project Title : **HELIOTRAM : 800 kWp PV POWER PLANTS FOR DIRECT INJECTION IN LIGHT TRAIN LOW VOLTAGE D.C. NETWORKS**

Abstract :

Public transportation low voltage D.C. networks are particularly well suited for direct connection of PV systems because of their electrical characteristics, since the load of the network coincides with the PV production. Very simple and therefore reliable PV power stations can be built to inject the solar production into such networks, without power conditioning.
In the framework of the Thermie 96 programme, Sunwatt Bio Energie SA presented and developed the project called Heliotram, which is aimed to the connected PV large Plants for injection in light train low voltage D.C. networks.
The purpose of this project is to manufacture and install such PV power plants in Germany (250 kWp at Hannover) and in Switzerland (150 kWp at Geneva and 100 kWp at Lausanne). This implies:

- Direct connection of series of PV modules to 600-750V DC grid, i.e. peak voltages up to 1'500V at open circuit by cold weather.
- Incite the manufacturers to certify their PV modules for a high voltage usage.
- Testing high speed circuit breakers and power contactors, for DC high voltages.

The system of TPG, at Geneva - 154 kWp - has started operating in July 1999. Some results on the system behaviour and performances are presented. The Lausanne project is presently divided into three installations totalising 46 kWp. The first one is in operation since March 2000, the two other ones are just starting in December 2000. Some convenient roofs have still to be found for constructing the remaining 56 kWp plant.

Duration of the Project : 1997 - 2001

Responsible for the project : Sunwatt Bio Energie SA

Reporting on the project : Sunwatt Bio Energie SA
Service de l'Energie Lausanne

Address : Sunwatt Bio Energie SA
9, rue Peillonnex, CH-1225 Chêne-Bourg

Telephone : +41 22 348 73 66 **Fax :** +41 22 348 73 53

http://www.sunwatt.ch **Email :** schneider-m@bluewin.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : 14578
Contract Number : 63527

Project Title : Visualisation and Analysis of the Data of the 4,1kWp PV-Power Plant Rothorn

Abstract :

The 4,1kWp PV-Power Plant is part of the building on top of the Rothorn (2865 m). It is an attraction to the public because the PV-panels are situated directly in front of the visitors terrace.
The aims of the present project are:

- Provide information to the public in order to familiarize interested persons with the possibilities and the qualities of the photo-voltaic technology.
- Analyze the effects of high altitude and severe weather conditions to the production of electrical energy considering the fact that the PV-Power Plant is part of the building.

The data logging for about one year is finished and the measurement data evalutation is now being started. The final report will be finished by the end of February.

Duration of the Project : 1997 until 2001

Responsible for the project : Max Schalcher

Reporting on the project : Max Schalcher

Address : Hochschule für Technik + Wirtschaft Chur
Ringstrasse
7000 Chur

Telephone : 081 / 286 24 46
http://www.fh-htachur.ch

Fax : 081 / 286 24 00
E-mail : max.schalcher@fh-htachur.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number: 26'746
Contract Number: 66'583 **PSEL Project No.:** 159

Project Title: **NOK's 1-Megawatt Solar Chain, Normalized Data 1997 to 2001**

Abstract:
The aim of this project is the calculation of the monitored operational data of all pv-installations of the **1-MW-Solar-Chain** according to the current guidelines of the ESTI at Ispra and the IEA. It is the continuation of the preceding project "NOK's 1-Megawatt-Solar Chain, Normalized Data 1992 - 1996" (PSEL-project No. 81, BFE-project No. 14'516 / 54'074).
The report **"Normalized Data 1999"** was completed and distributed to the clients this year. It contains detailed evaluation of 1999's data as well as summaries over the whole period from 1992 until 1999. The reported stations are: NOK-Headquarters Baden, ISOKW Brugg, Alp Findels, Church of Steckborn, Disentis-Caischavedra (Desertasol), Migros-Winterthur, Neu-Technikum Buchs and, for the first time, the station of Vorderberg, owned by the Electricity Supply Company of Buchs.
The detailed observation of the photovoltaic plants over their lifetime provides important experience concerning aging, degradation and long-term reliability of the components used.

Duration of the Project: January 1997 - March 2002

Responsible for the project: Stefan Roth

Reporting on the project: Stefan Roth

Address:
Axpo
New Energy Systems Dept.
Weststrasse 50
Postfach 9880
8036 Zürich

Telephone: 01 457 31 45 **Fax:** 01 457 31 32

http://www.axpo.ch E-mail: stefan.roth@axpo.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number : 23844
Contract Number : 63884

Project Title : **Monitoring of the 180 kWp PV-Power Plant of UBS Suglio/Lugano**

Abstract :

The goal of the project is the monitoring of the behaviour of the UBS Suglio/Lugano photovoltaic power plant. This system consists of four parts :

- two parts on the roof, each of 73.5 kWp, with each a central inverter
- one part on the facade of eastern wing, 20 kWp
- one part on the facade of the western wing, 16 kWp

Three of the parts have central inverters, the facade of the western wing has string inverters.

Project works have begun in the second half of 1998 and were continued in the year of 1999. The main goal, data acquisition and calculation of the first results have been achieved in 1999. Interesting results, specially concerning UPS-function, were found.

It has also been shown, that an intense monitoring of a PV-installation raises the energy production thanks to a quicker response to problems.

Duration of the Project : October 1998 – December 2000

Responsible for the project : Enecolo AG, UBS, TISO - LEEE, Scuola Universitaria Professionale

Reporting on the project : Robert Kröni, Enecolo AG, 8617 Mönchaltorf
Enrico Burà, TISO – LEEE, 6952 Canobbio

Telephone : 01 / 994 90 01 **Fax :** 01 / 994 90 05

http://www.solarstrom.ch **E-mail :** info@enecolo.ch

Bundesamt für Energie
Office fédérale de l'énergie
Ufficio federale dell'energia
Swiss federal Office of Energy

Programme in Photovoltaic Energy Conversion

ANNUAL REPORT 2000

Project Number: 32046
Contract Number: 71920

Project Title: 100 kWp PV-Netzverbundanlage A13 - Messkampagne, Periode 99-2001

Abstract:

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

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

The plant produces on average 110‘000 kWh per annum at a specific annual yield of 1‘030 kWh/ kWp. The plant operated for the first 10 years without any mayor interruptions. In the 11nt year however, through a series of unfortunate events there was a mayor interruption and as a consequence one third of the annual energy production was lost.

In the year 2000 the plant produced 65'405 kWh or 618 kWh / kWp with a performance of 45 % and an availability of 63%.

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

Duration of the project: Jan. 1999 to Dec. 2001

Responsible for the Project: TNC Consulting AG

Reporting on the Project: L. Clavadetscher, Th. Nordmann

Address: TNC Consulting AG
Seestrasse 141
8703 Erlenbach
Switzerland

Telephone: 01 / 991 55 77 **Fax:** 01 / 991 55 87

http://www.tnc.ch **E-Mail:** luzic@tnc.ch, nordmann@tnc.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number : 35527
Contract Number : 75305

Project Title : **Coating of PV-Modules**

Abstract :
PURPOSE AND GOALS OF THE PROJECT:
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 in two parallel investigations: laboratory investigations for a systematic screening of different glass/coating combinations and a "real term" investigation in an existing power plant.
MOST IMPORTANT RESULTS IN 2000:
Laboratory investigations

- Evaluation and measurements of a large set of glass/coating combinations
- Detection of material problems during exposition: it is necessary to order and prepare a large new batch for exposition. Re-establish measurements in early 2001.

"Real term" investigations

- Construction and validation of the experimental setup successful
- Due to further developments in coating technology, the experimental modules were re-coated and the measurement campaign is re-established since December 1st, 2000.

Duration of the Project : September 1999 - January 2004

Responsible for the project : Dr. Andreas Schlegel

Reporting on the project : Dr. Andreas Schlegel

Address : awtec AG für Technologie und Innovation
Leutschenbachstrasse 42
8050 Zürich
Switzerland

Telephone : ++41 1 307 4060 **Fax :** ++41 1 307 4061

http://www.awtec.ch **Email :** andreas.schlegel@awtec.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : 17967
Contract Number : 57555

Project Title : **Normenarbeit für PV Systeme**

Abstract: Global recognition of the quality and legitimacy of its technical work as an international standards organisation is among the IEC's major strengths. But this is not yet always perceived by the PV industry management, which does not always fully appreciate what the IEC is and why its work, with that of its National Committees, makes a major contribution to the continuing rapid growth of trade in PV electrotechnical products and systems.

The standards for PV Systems are worked out by Technical Committee 82 (TC82) , which has the following Scope: To prepare international standards for systems of Photovoltaic conversion of solar energy into electrical energy and for all the elements in the entire Photovoltaic energy system. TC 82 is organised by 7 working groups:

WG 1: Glossary
WG 2: Modules, non-concentrating
WG 3: Systems
WG 4: PV energy storage systems
WG 5: Quality and certification
WG 6: Balance-of-system components
WG 7: Concentrator modules

Details on the actual work being performed by individual WG's can be looked up under http://www.iec.ch.
Switzerland is actively involved in the TC 82 work and WG3, where PV system related standards are elaborated. As a P-Member, Switzerland can have direct impact on all the standards being worked out under TC82. The Swiss platform to discuss these topics is the national "Technische Komitee 82" (TK82). All related documents are circulated to their members for discussion, either by writing or in regular meetings. Among the many standards being worked out at present, the most important one's for the Swiss PV Industry are related to PV on buildings, Solar Home System type approval testing and inverter safety and testing. Interested individual experts or companies can apply to become part of this important process by applying at Mr. Josef Schmucki, SEV, Fehraltorf or the author of this report.

Duration of the Project : 1.1.1998 – 31.12.2000

Responsible for the project : Markus Real

Reporting on the project : Markus Real

Address : Alpha Real AG,
Feldeggstrasse 89, 8008 Zürich

Telephone : +41 1 383 02 08 **Fax :** +41 1 383 18 95

http://www.iec.ch **Email :** alphareal@access.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number: 21280
Contract Number: 65847

Project Title: **PVSYST 3.0 Ergonomie et fonctionnalité**

Abstract:

Three objectives were defined for this year :

- Collect the comments and bug reports from the users of version 3.0, implement the corrections and the accepted suggestions and improvements in the program.
- Finalise the website, open a user's forum.
- Publish the results of the project

Results :
The program is now available in version 3.1 with several improvements.
It has been used by the participants of the IEA international design competition with success.
Results have been presented in Sydney, Glasgow and Neuchâtel
The website is open, with forum space (http://www.pvsyst.com/)

Duration of the Project: 1st of July 1998 - 31st of December 1999
Extended : 30 June 2000

Responsible for the project: Ch. Roecker

Reporting on the project: Ch. Roecker

Address: EPFL - Bâtiment LESO 1015 Lausanne
CUEPE, Battelle bât A, 7, rte de Drize,
1227 Carouge/GE

Telephone: ++41 021 693.43.41 **Fax:** ++41 21 693 27 22

http://www.pvsyst.com/

Email: christian.roecker@epfl.ch - andre.mermoud@cuepe.unige.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number: 29946
Contract Number: 69842

Project Title: Guarantee of Solar Results for Grid-Connected-Photovoltaic-Systems 'GRS-PV'

Abstract: The installation of 500.000 grid-connected PV systems needs a contractual framework that ensures high-quality, high guarantee PV systems. Once properly established the GRS-PV model can provide this framework for PV systems ranging from AC-modules to multi megawatt systems. The GRS-*PV* concept is easily understandable and convincing for investors. For a further utilisation mainly installers hesitate to do so as it was not clear on how to determine the costs and measures connected with certain guarantees.
The main objective of this project is the validation of the GRS-*PV* concept. The first step was the establishment of a mutually agreed structure on aspects impacting the quality of PV-systems. In addition, an assessment of would-be benefits for a contractual agreement between PV-installer and PV-investor was created.

In a second step the would be benefits and the possible implementation of the concept in new projects with interested companies will be addressed. Following the development of the model in previous GRS-contracts, and the first attempts to apply the model in projects, the concept shall be validated, in particular the cost effectiveness and its appropriateness for PV industry. This task will be realised in close cooperation with specialised companies and projects which want to utilise the GRS-concept.

It is expected that a validated GRS-*PV* concept will have a positive impact on the deployment of PV systems.

Duration of the project: July 1999 - December 2000

Responsible for the project: Christian Meier
Reporting on the project: Christian Meier, Peter Eichenberger
Address : energiebüro
Limmatstrasse 230
CH-8005 Zürich/Switzerland
Telephone : ++ 41 1 242 80 60
Fax : ++ 41 1 242 80 86
Internet-Hompage: http://www.energieburo.ch
Email : info@energieburo.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number: 35547
Contract Number: 75306

Project Title:	**HORIZsolar – Development of a new and cost-effective instrument for a up-to-date and accurate pick-up of the horizon**

Abstract:

HORIZsolar is a new 360°-panorama-tool and a picture-handling software for the photometric determination of the horizon. With the camera-help panoramaMaster accurately aligned pictures are taken up, which are merged with the software horizON to a 360°-Panorama. The horizon will be calculated automatically.

During the winter term 1999/2000, the software horizON was developed in its fundamentals. Since autumn 1998 the panoramaMaster is being developed. Up to today, 2 prototypes of the panoramaMaster were produced, and a first version of horizON also.

The status of the development shows for the prototypes of the first generation some typical lacks such as unsatisfactory functionality and insufficient customer friendliness.

Duration of the Project:	October 1999 – December 2000

Responsible for the project: energiebüro

Reporting on the project: Frei Roland

Address: energiebüro
Limmatstrasse 230
CH-8005 Zürich

Telephone: 01 / 242 80 60 **Fax:** 01 / 242 80 86

http://www.energieburo.ch **Email:** info@energieburo.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : 38268
Contract Number : 78044

Project Title :	**Feasibility Study "PV installations with Thin-film Cells integrated into football stadiums"**

Abstract :

The dimensioning of big photovoltaic installations (P > 100 kWp), based on crystalline silicon, is well-known today. Also the rules for a good integration into the skin of the buildings are well-known and used successfully. But in one field, experience are still not made:
The electrical an mechanical dimensioning of big PV installations based on Thin-film Cells, for example amorphous silicon or CIS (Copper-Indium-Diselenide).

In the next few years, some football stadiums will be built in Switzerland. All these buildings show large roof areas which could be used for PV-generated energy. This is a great chance to collect such experience.

These questions should be answered by a concrete example. A few participants (Building-owner, Energy-distributor, Investors and so on) are interested in the designated building. The object of the feasibility study is to evaluate open questions in the field of electrical an mechanical dimensioning.

Duration of the Project :	July 2000 – March 2001

Responsible for the project : Ingenieurbüro Hostettler, Bern

Reporting on the project : Th. Hostettler

Address : Wankdorffeldstr. 64
3014 Bern

Telephone : 031 / 332 12 42
http://

Fax : 031 / 332 12 41
Email :
Hostettler_Engineering@compuserve.com

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number : BBW 99.0569
Contract Number :

Project Title : **PV City Guide**

Abstract:

Purpose of the work: The objective of PV City 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.

Approach: The PV City Guide is being designed for practical use by the target groups in order to facilitate the implementation of future PV projects. Draft guides have been produced after consulting local experts and actors regarding local need. These drafts are being improved through feedback from local and national target groups and consultation in relation to ongoing BIPV projects. The PV City Guide will achieve objectives in terms of contribution to European Union (EU) policies regarding renewable energy systems (RES) and also to community social objectives by attention to local involvement and replicability. PV City Guide partner cities are Barcelona, Basel, Bristol, Brussels, Florence, Gothenburg, Malmö, The Hague and Zurich. By concentrating on the needs of and strong interaction with the defined target audience, the PV City Guide is providing a new approach towards future activities in this field.

Results: The project will result in a comprehensive set of information, instruments, checklists, calculation forms, etc. which can be used as an urban design tool for the field of integration of photovoltaics in the urban environment.

Duration of the Project : January 1st 2000 - December 31st 2001

Responsible for the project : Stefan Nowak, NET Ltd; Mike Barker, ICERDA

Reporting on the project : Marcel Gutschner, NET Ltd

Address : NET Nowak Energy & Technology Ltd
Waldweg 8
1717 St. Ursen

Telephone : +41 (0)26 494 00 30 **Fax :** +41 (0)26 494 00 34

http://pvcityguide.energyprojects.net **Email :** marcel.gutschner.net@bluewin.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

Programme
in Photovoltaic
Energy Conversion

ANNUAL REPORT 2000

Project Number: 10230
Contract Number: 50191

Project Title: **PV on vocational Colleges in Switzerland, 7 Years Experience in Training and Education**

Abstract:
Within the framework of the Swiss Photovoltaic Programme for Vocational Colleges, 21 of the 60 vocational school centres in Switzerland were equipped with a photovoltaic installation. 4'300 apprentices or 42% of all electricians being educated in 1998 attended these vocational colleges. This means that the electricians programme for vocational colleges reaches almost 50% of all future electric installations professionals in Switzerland.

Specific know-how and applications experience are introduced and integrated on a step-by-step basis into the normal theoretical curriculum. Continual checking of results and a measurement campaign document the high technical level of this application of PV.

This user-group is further supported by an information network consisting of yearly experience-exchange conferences, a newsletter and an internet website (http://www.pv-berufsschule.ch)

Duration of the Project: August 1992 to December 2000

Responsible for the project: Th. Nordmann

Reporting on the project: Th. Nordmann, A. Frölich

Address: TNC Consulting AG
Seestrasse 141
8703 Erlenbach

Telephone: 01 / 991 55 77 **Fax:** 01 / 991 55 87

http://www.pv-berufsschule.ch **Email:** mail@tnc.ch
http://www.tnc.ch

Bundesamt für Energie
Office fédéral de l'énergie
Ufficio federale dell'energia
Swiss Federal Office of Energy

**Programme
in Photovoltaic
Energy Conversion**

ANNUAL REPORT 2000

Project Number :
Contract Number :

Project Title : Photovoltaic Energy Statistics of Switzerland 1999

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.

It was shown, that the annual average yield of all PV installations in Switzerland is at above 840 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 % considered very good for technical systems.

The number of PV installations in Switzerland is steadily growing. Per January first 1999, an estimated 1100 PV systems will be installed in Switzerland adding up to 9.5 MWp overall system power. Taking delayed start of operation of new built systems into consideration, the overall production of electricity for 1996 added up to 7'100 MWh.

To observe and follow up on individual PV installation performances over the years, a new data base is currently under erection. With this new aid it is expected to be able to show system performance in the range of decades, discovering possible decrease of power output with a high statistical significance.

Detailed investigation into the quality, yield, and deployment of PV in Switzerland over the last eight years has shown results about the development of the technology as well as the market. The research focused on following areas:

- overall yield and contribution of PV in Switzerland
- large scale QA for grid connected PV systems
- analysis of weak performing PV installations

Additional investigation revealed large differences in the annually available irradiation of up to 7%; based on the last 10 year average.

Duration of the Project : 1998 – 2001

Responsible for the project : energiebüro

Reporting on the project : Christian Meier

Address : energiebüro
Limmatstrasse 230
CH-8005 Zürich

Telephone : 01 / 242 80 60 **Fax :** 01 / 242 80 86

http://www.energieburo.ch **Email :** info@energieburo.ch