IEA International Energy Agency
IMPLEMENTING AGREEMENT ON PHOTOVOLTAIC POWER SYSTEMS

Task 1
Exchange and dissemination of
information on PV power systems

National Survey Report on PV Power Applications in Switzerland 2005

Prepared by
Nova Energie GmbH
Schachenallee 29
CH-5000 Aarau

Mai-August 2006

On behalf of
Swiss Federal Office of Energy

List of Contents

i Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the organisation for Economic Co-operation and Development (OECD), which carries out a comprehensive programme of energy co-operation among its 23 member countries. The European Commission also participates in the work of the Agency.

The IEA Photovoltaic Power Systems Programme (IEA-PVPS) is one of the collaborative R & D agreements established within the IEA and, since 1993, its participants have been conducting a variety of joint projects in the applications of photovoltaic conversion of solar energy into electricity.

The nineteen participating countries are Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Mexico (MEX), The Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), The United Kingdom (GBR) and The United States of America (USA). The European Commission is also a member.

The overall programme is headed by an Executive Committee composed of one representative from each participating country, while the management of individual research projects (tasks) is the responsibility of Operating agents. Eleven tasks have been established, and currently six are active. Information about these tasks can be found on the public website www.iea-pvps.org. The objective of Task 1 is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of photovoltaic power systems.

This report has been prepared under the supervision of Task 1 by

Pius Hüsser, Nova Energie GmbH, Aarau
Thomas Hostettler, Ingenieurbüro Hostettler, Bern
Alan C. Hawkins, A.C.Hawkins Consulting & Services, Erlinsbach

ii Introduction

This National Survey Report gives a brief overview of what has been achieved in the photovoltaic (PV) power area in Switzerland in the year 2005. It is only a summary of the most important developments and applications of photovoltaic power systems and does not pretend to be complete in any way. A more comprehensive view of PV research and pilot / demonstration plant is available from the Swiss national photovoltaics website (www.photovoltaic.ch).

iii Definitions, symbols and abbreviations

For the purposes of the National Survey Reports, the following definitions apply:

PV power system market: The market for all nationally installed (terrestrial) PV applications with a PV power capacity of 40 W or more.

Installed PV power: Power delivered by a PV module or a PV array under standard test conditions (STC) – irradiance of 1 000 W/m2, cell junction temperature of 25oC, AM 1,5 solar spectrum – (also see 'Rated power').

Rated power: Amount of power produced by a PV module or array under STC, written as W.

PV system: Set of interconnected elements such as PV modules, inverters that convert d.c. current of the modules into a.c. current, storage batteries and all installation and control components with a PV power capacity of 40 W or more.

Module manufacturer: An organisation carrying out the encapsulation in the process of the production of PV modules.

Off-grid domestic PV power system: System installed to provide power mainly to a household or village not connected to the (main) utility grid(s). Often a means to store electricity is used (most commonly lead-acid batteries). Also referred to as 'stand-alone PV power system'. Can also provide power to domestic and community users (plus some other applications) via a 'mini-grid', often as a hybrid with another source of power.

Off-grid non-domestic PV power system: System used for a variety of industrial and agricultural applications such as water pumping, remote communications, telecommunication relays, safety and protection devices, etc. that are not connected to the utility grid. Usually a means to store electricity is used. Also referred to as 'stand-alone PV power system'.

Grid-connected distributed PV power system: System installed to provide power to a grid-connected customer or directly to the electricity grid (specifically where that part of the electricity grid is configured to supply power to a number of customers rather than to provide a bulk transport function). Such systems may be on or integrated into the customer's premises often on the demand side of the electricity meter, on public and commercial buildings, or simply in the built environment on motorway sound barriers etc. They may be specifically designed for support of the utility distribution grid. Size is not a determining feature – while a 1 MW PV system on a rooftop may be large by PV standards, this is not the case for other forms of distributed generation.

Grid-connected centralized PV power system: Power production system performing the function of a centralized power station. The power supplied by such a system is not associated with a particular electricity customer, and the system is not located to specifically perform functions on the electricity grid other than the supply of bulk power. Typically ground mounted and functioning independently of any nearby development.

Turnkey price: Price of an installed PV system excluding VAT/TVA/sales taxes, operation and maintenance costs but including installation costs. For an off-grid PV system, the prices associated with storage battery maintenance/replacement are excluded. If additional costs are incurred for reasons not directly related to the PV system, these should be excluded. (E.g. If extra costs are incurred fitting PV modules to a factory roof because special precautions are required to avoid disrupting production, these extra costs should not be included. Equally the additional transport costs of installing a telecommunication systems in a remote area are excluded).

Field Test Programme: A programme to test the performance of PV systems/components in real conditions.

Demonstration Programme: A programme to demonstrate the operation of PV systems and their application to potential users/owners.

Market deployment initiative: Initiatives to encourage the market deployment of PV through the use of market instruments such as green pricing, rate based incentives etc. These may be implemented by government, the finance industry, utilities etc.

Final annual yield: Total PV energy delivered to the load during the year per kW of power installed.

Performance ratio: Ratio of the final annual (monthly, daily) yield to the reference annual (monthly, daily) yield, where the reference annual (monthly, daily) yield is the theoretical annual (monthly, daily) available energy per kW of installed PV power.

Please also refer to the internal PVPS report Writing numerical values, quantities, units and symbols according to International Standards for guidance

1 Executive summary

In 2005 Switzerland set a new record in installed capacity of nearly 4 MWp. This is due to two installations both commissioned by utilities: The 1 MW ground mounted plant by the utility of Geneva (Service Industriel de Geneve) and the roof top 855 kW plant on the newly built soccer stadium in Berne (BKW Bernische Kraftwerke).

Despite this highlights, compared to neighbouring countries, the outlook for a prospering home market are still unsecure. Depending on the outcome of the political debate during 2006, on the new electricity law, concerning the future promotion of renewable electricity, the situation could change to a more favourable situation by 2008 at the earliest.
Swiss industry, especially equipment manufacturers, did very well on the international market thus profiting from the favourable international conditions and the booming market.

Installed PV power

Total installed PV power in Switzerland rose once more in 2005 and reached a total of around 27 MW of which around 24 MW was delivered by grid-connected installations. This is the highest ever increase in one year. Total installed capacity in 2005 was about 4 MW, almost half of it coming from the to biggest PV plants in Switzerland, the roof mounted 855 kW on the football stadium in Bern and the ground mounted 1 MW plant of the Geneva utility in Geneva.
Besides those two very large installations, their was still a market for commercial investors where there are solar stock exchange schemes in operation. This counts especially for the Geneva utility SIG, which contracted another 700 kW to private investors.

Costs & prices

Switzerland is fully depending on the European module market. Thus, the price also for large and small installations increased in 2005 due to an increase in module prices from roughly 10 percent. For residential systems the price went up to an average of 10 Swiss francs per Watt and for large scale system (above 100 kW) the average prices has been reported at 7,5 to 9,0 Swiss francs.

PV industry

The equipment manufactures in Switzerland, mainly the two wire saws manufacturers, profited very well from the booming market. Meyer & Burger reported they had to hire another 100 people in the last two years in order to serve the growing demand for their machinery.

Unaxis Solar was successful in bringing their newly developed thin film process equipment to the market thus profiting from a growing demand for alternatives to the crystalline cell market. This is also a success for the Swiss government funded R&D programme which concentrated in the last couple of years on thin film solar cells technology development.

With Swiss Sustainable Systems (3S) the first PV company from Switzerland got enlisted on the stock exchange in Berne and Frankfurt.

Sputnik engineering, the Swiss inverter manufacturer, kept it's market share on the European market with a strong position in Germany and expanding business in Spain.

The estimated PV-related industry turnover in Switzerland in 2005 is estimated to CHF 300 Mio.

Budgets for PV Promotion

Since the cut back of P+D budgets by the Swiss Confederation in 2003, no new projects could be started in 2005. Despite this, there are still some projects in progress, among them several dealing with thin film cells installations and performance measurements.

Although on a regional level, subsidies are only available in very few cantons, for private investors on their on home, there is still an income tax deduction scheme in force in almost all of the cantons. This can be as high as one third of the installations costs depending on the income.

2 The implementation of PV systems

The PV power system market is defined as the market of all nationally installed (terrestrial) PV applications with a PV capacity of 40 W or more. A PV system consists of modules, inverters, batteries and all installation and control components for modules, inverters and batteries.

2.1 Applications for photovoltaics

In Switzerland, the majority of PV Installations are grid-connected plant, built mostly on the roofs of buildings. Larger installations (> 50 kW) are usually flat-roof mounted on commercial buildings, offices etc.
The smaller grid-connected PV installations (typically around 3 kW) can normally be found on the roofs of single-family homes. Traditionally, off-grid installations for week-end chalets and alpine huts are relatively small (< 1 kW).
In 2005 in exception to the above mentioned the utility of Geneva (SIG) installed the largest PV plant in Switzerland (1 MW) on the open ground (Ground mounted).

The remarkable market growth in 2005 is mainly due to several more installations (besides the 1 MW plant) within the market area of the utility of Geneva (SIG) and the commissioning of the world famous PV installation on the football stadium in Berne (850 kW).

2.2 Total photovoltaic power installed

Our assessment is based on the following data:

Swiss Federal Office of Energy / Swiss Association of Electricity Enterprises, PV Statistics 2005

Swissolar (Swiss Professional Association for Solar Energy) annual survey of PV sales for 2005.

Table 1 The cumulative installed PV power in 4 sub-markets.

Sub-market/ application	31 Dec. 1992 kW	31 Dec. 1993 kW	31 Dec. 1994 kW	31 Dec. 1995 kW	31 Dec. 1996 kW	31 Dec. 1997 kW	31 Dec. 1998 kW	31 Dec. 1999 kW	31 Dec. 2000 kW	31 Dec. 2001 kW	31 Dec. 2002 kW	31 Dec. 2003 kW	31 Dec. 2004 kW	31 Dec. 2005 kW
off-grid domestic	1 540	1 675	1 780	1 940	2 030	2 140	2 210	2 300*	2 390*	2 480*	2 570*	2 740*	2 810*	2 930*
off-grid non-domestic	70	100	112	143	162	184	190	200*	210*	220*	230*	260*	290*	320*
Grid-connected distributed	2 200	2 900	3 600	4 050	4 850	5'950	7 630	9 420	11 220	13 340	15 140	16 440	18 440	21 240
Grid-connected centralised	900	1 100	1 200	1 '350	1 350	1 450	1 470	1 480	1 480	1 560	1 560	1 560	1 560	2 560**
TOTAL	4 710	5 775	6 692	7 483	8 392	9 724	11 500	13 400	15 300	17 600	19 500	21 000	23 100	27 050

* Author's estimates. Exact figures for the proportion of off-grid power for domestic and non-domestic applications are not available.

** In 2005 newly built 1 MWp System, ground mounted, in Geneva

Compared with 2004, cumulative installed power increased by around 88%. In spite of the unfavourable political situation concerning the promotion of solar power, the installations of several larger PV plant for "solar stock exchanges" led to a remarkable increase.

Figures for on-grid centralised plant cover larger installations that are operated on the production side (often by utilities or public authorities) and are not integrated into buildings (i.e. free-standing plant and installations on noise-barrier structures.

On-grid distributed covers building-integrated plant on houses, offices, factories etc. (usually privately owned) They are often used for in-house generation (e.g. single family homes) or supply energy for "solar stock-exchanges". The latter installations are mostly in the range of 50 kW to 250 kW.

2.3 Major projects, demonstration and field test programmes (see also www.photovoltaic.ch)

At the beginning of 2005, 25 projects were still active in the P+D area. By the end of the year, 13 further projects were completed so that a 12 projects still remained. The negative influence on new P+D - projects feared after decisions to cut back funding were made (in 2003) hit with full force. As a result, further deficiencies in the realisation phase are impending.

Luckily, the activities of the electricity utilities active in the field of solar power "stock-exchanges" increased slightly once more and thus prevented an all too marked reduction in market activities. In this connection, we are happy to note the efforts of the two electricity utilities BKW and SIG, who, on their own initiative, each built and put into operation a large photovoltaic installation. The BKW's "Stade de Suisse" project with an installed power of 855 kWp was already briefly presented here last year. Its well-thought-out construction and, in particular, the hand trolley specially developed for maintenance purposes led to this plant being awarded both the Swiss and the European Solar Prizes. The SIG II plant, with a peak power of 1 MW, was built and put into operation in 2005. At the moment this is the largest mains-connected PV plant in Switzerland.

Projects concluded in 2005:

The most important of the 13 projects finished in 2005 are described briefly below.

"Zollhof" 23.5 kWp photovoltaics installation in Kreuzlingen
In addition to the use of predominantly regional components, the aim of this installation was to achieve a high level of public identification and to bring PV-technology as close to the general public as possible. Thanks to a prominently mounted production display, the goals of this largest PV installation in the canton of Thurgau were reached successfully. In spite of the failure of three of the system's six inverters, the installation was able to deliver a specific yield of 944 kWh/kWp in 2005.

Trisa Electro 62.4 kWp photovoltaics installation in Triengen
On the roof of the new logistics centre of the Trisa Electro company, more than 600 m2 of "PowerGuard" flat-roof elements were installed, the whole plant being put into operation in January 2004. The measurements made indicated a specific yield of around 860 kWh/kWp, which was above expectations.

Measurement campaign on the 24.5 kWp thin-film test installation at Migros in Zurich
In a complex project, the power-production of thin-film modules using different technologies (aSi, CIS and, as a reference, multi-crystalline silicon) supplied by 6 different manufacturers in three different configurations (flat and insulated / flat and back-ventilated / sloping and back-ventilated) was measured in detail for more than 2 years. The results are available in standardised form and clearly show the advantages of thin-film technology when used in building-integrated applications (i.e. at higher temperatures). On the other hand, the results concerning capital expenditure and reliability were not always pleasing.

Implementation of IEC standard 60364-7-712
Work on the integration of the new IEC standard 60364-7-712 in Swiss NIN standards was concluded at the end of 2004. The translations into French and Italian by Electrosuisse were completed in spring 2005 and a well-visited course for the electrical installation business was organised. In this way, the installation regulations will become general knowledge for all specialists in the electrical installation profession in the future. For the PV trade this may be a small loss of exclusivity, it is, however, an important step towards becoming a "normal" profession!

GISS Study
In a widely-supported study by the Swiss Central Office for Window and Facade Construction SZFF, a number of authors looked at various sub-areas such as basic principles, identification of obstacles inhibiting the use of photovoltaics, reduction of information shortcomings and increasing the competencies of SZFF members. On the basis of market statistics, a gigantic potential lying unused as a result of a lack of information was identified. The facade-builders call for simpler, structured procedures as well as a clear division of work between facade builders and PV specialists. Future fields of activity were identified.

On-going projects:

A selection of on-going projects with their intermediate results is briefly presented below.

25 kWp “Solgreen Power Station 1” in Zurich
The intermediate results confirm that a favourable microclimate is developing. Pleasing specific yields of around 1000 kWh/kWp were noted. On the basis of measurements made on pH-values, it was also confirmed that the materials employed are compatible with the substrates used.

“CPT Solar” 15.4 kWp photovoltaics installation in Trevano
The measurements made up to now impressively confirm the potential of this concept (flat-roof integration of aSi triple cells). Specific yields reach values clearly above the 1000 kWh/kWp mark (2004: 1070 kWh/kWp; 2005: 1077 kWh/kWp).

PV energy statistics 2005
The year 2005 was very successful thanks to slightly higher insolation and two progressive power utilities (see above). An increase of 3,95 MW of peak power was achieved, meaning that, by the end of 2005, PV installations with a total installed power of 27 MW were producing clean power. The around 5 % higher insolation level led to an average specific yield of 820 kWh/kWp. Newly built installations achieve up to 1 000 kWh/kWp.

Summary of major projects, demonstration and field test programmes

The following table lists a selection (by no means complete) of interesting Swiss P+D projects that were still active in 2005.
As a result of cut-backs in government funding, no new P+D projects were started in 2005

Project Date plant start-up	Technical data/Economic data	Objectives	Main accomplishments by the end of 2005 /problems and lessons learned	Funding	Project management	Remarks
Stade de Suisse: Sport and Event Arena in Berne, 2004/5	855 kW installation on the roof of the new Swiss national Stadium in Berne. Option for extension to 1 300 kW	The largest “solar stock exchange” installation in Switzerland. Information platform for the public on solar power	The official inauguration took place in 2005; annual production exceeded more than 700 MWh	Private (Utility)	BKW-FMB	Information centre above the roof
CPT Solar - Flat roof integration, TISO, Trevano, 2003	Test of roofing product featuring the combination of solar cells and waterproofing membranes	Test of flexible triple-junction amorphous thin-film cells bonded to plastic foil. Assessment of thermal effects	Monitoring is active and shows very good system performance (> 1000 kWh/kWp)	Private, SFOE	SUPSI, DACD, LEEE-TISO, Cannobio	3 small open-rack installations with a-Si and c-Si for comparison
62 kW PV installation Triengen, 2003	Combined Power Guard insulation/PV roofing system on a high-bay warehouse	Test of solar roofing elements consisting of 5 cm insulation with 2 bonded laminated PV panels	Installation has been connected to the grid since January 2004; measuring-period of 16 months shows better performance than expected	Private, SFOE	Zagsolar, Kriens, Trisa Electro AG, Triengen	Production display to be mounted on nearby transformer station.

2.4 R&D Highlights (see also www.photovoltaic.ch)

In the field of research, the level of activities was held approximately constant thanks to the broad support given to the programme. Industrial implementation of previous research results is still given high priority. The continuous growth of the international photovoltaics market forms - in spite of a stagnating national market - an important basis for the decisive expansion of the photovoltaics industry basis in Switzerland that is occurring at present. This means that the photovoltaics programme shows a pronounced orientation towards the transfer of know-how to industry and towards international competitiveness, both for products as well as for the research that precedes it. Current activities in the research and development area as well as projects in the area of pilot and demonstration installations that still exist encompassed around 65 projects for the year 2005, whereby all known projects that enjoy promotion by public authorities are considered. A short (and incomplete) review is given below:

CELL-TECHNOLOGY

The large bandwidth of Swiss solar cell research was successfully maintained in the year under review thanks to the broad support offered to this research. In 2005 new industry projects were started with the help of the KTI. Participation in EU projects formed a further important component; new projects in the field of the thin-film solar cells were initiated. In this way, Switzerland is now involved in most of the European Commission's current integrated projects in the field of photovoltaics.

Thin-film silicon

Developments in the field of thin-film silicon are being carried out at the University of Neuchâtel (IMT), the Swiss Federal Institute of Technology EPFL in Lausanne (CRPP), the University of Applied Technology in Le Locle, the University of Applied Technology NTB (Buchs SG) as well as at the Unaxis Solar company (Truebbach, Neuchâtel) and VHF-Technologies (Yverdon). These represent important focal points of the Swiss photovoltaics programme.

In the year under review , the IMT at the University of Neuchâtel began a new, three year phase of the project involving thin-film silicon solar cells. The aims of this SFOE project include the further increase of the efficiency of solar cells on various substrates (target: 14% for "micromorph" solar cells), the further development of the processes involved and characterisation of the solar cells as well as assuring the availability of the infrastructure necessary (processes, production and characterisation) as a form of support for partners in industry.

The KTI project carried out in co-operation with Unaxis on a process for the fast deposition of microcrystalline silicon on the basis of KAI plasma deposition plants was continued in 2005. This method forms the basis for the large-area (1.4m²) industrial process for the production of micromorph solar cells. On the experimental installation at the IMT, microcrystalline silicon solar cells with an efficiency of 7.2% were produced. At the Unaxis facility, micromorph mini modules (10 x 10 cm2) with an efficiency of 9.5% were produced using this process.

A further KTI project involving the IMT and Unaxis is concerned with the stability of translucent oxide layers (TCO) made of ZnO in laminated solar cells in particular with

regard to the steam-heat test within the framework of the IEC tests for solar modules (IEC 61646: 1000h @ 85°C & 85% rel. humidity). It was demonstrated that the stability required by the test can be achieved.

In co-operation with Unaxis, the NTB in Buchs successfully continued work on the KTI project for a spectral response photocurrent measuring instrument (Spectral Response Measurement System SRMS) that is oriented towards industrial production. In 2005, two prototypes of this device were installed at Unaxis; initial results are very positive, in particular concerning the stability of the measurement method. With this system, full-surface measurements on solar modules can be carried out and the corresponding images can be displayed.

The IMT finished the KTI project run together with VHF-Technologies and further partners on the use of nano-structured optical gratings for the improvement of the characteristics of flexible solar cells on plastic substrates. The nano-structured plastic substrates (PET, PEN) were prepared using OVD-kinegrams. At the IMT, amorphous solar cells with a stable efficiency of 7.3% were produced on textured PET substrates. It was demonstrated that the nano-structured substrates produced by OVD-kinegrams are compatible with VHF-Technologies' fabrication process. In the course of the project, VHF-Technologies was able to clearly improve its manufacturing process. Since Autumn 2005, the IMT and VHF technologies are working together on this subject within the framework of the EU's new FLEXCELLENCE project. For the first time in the field of photovoltaics, project coordination is being carried out by a Swiss partner (IMT).

II-VI combinations (CIGS)
The thin-film physics group at the Federal Institute of Technology ETHZ in Zurich has been involved for many years in EU projects concerning solar cells on the basis of semiconducting compounds (CIGS, CdTe). In the year under review, the development of flexible CIGS solar cells was driven forward within the framework of the SFOE's FLEXCIM project. The world record of 14.1% for the efficiency of flexible solar cells on plastic set up in the previous year on polyimide still represents the highest value yet reached. In 2005, work was done on the up-scaling of the process to 30x30 cm2.

The EU project NEBULES on subject of new buffer layers for CIGS solar cells was concluded in 2005. Here, the ETHZ group concentrated on the structural, chemical and electronic characterisation of the solar cells and their dependence on CDS as well as InS buffer layers produced by various means. The boundary surfaces with the InS buffer layers were analysed in detail with regard to structure and composition.

The thin-film physics group at the ETHZ has been continuing this work since autumn 2005 within the framework of the new EU LARCIS project. In this case, questions of the large-scale transfer of various key topics to industrial production are being looked at. Moreover, the group also became successfully involved in the new EU ATHLETE project (compare with above) and will do work on the part of the project concerning CIGS solar cells.

Dye cells

The development of dye-sensitised, nano-crystalline solar cells was continued at the ISIC at the EPFL. In the year under review, further developments on the particle characteristics of the TiO2 films were made. The synthesis of dyes and work on the electrolytes used concentrated on their stability at higher temperatures (around 80°C). In this way, a service life of the dye cells of 10 to 20 years can be aimed for.

The EU's MOLYCELL project is concerned with flexible organic solar cells, whereby both completely organic and hybrid nano-crystalline-organic solar cells are being developed. The latter are at the centre of the EPFL's attention, whereby a fixed hetero-junction between nano-crystalline metallic oxides and molecular and polymeric hole conductors is being worked on. Light-absorption is influenced by the molecular dyes and polymers. The ISIC produced first flexible dye cells on titanium films and, up to now, an efficiency of around 2% has been achieved.

Solaronix is involved in the EU's FULLSPECTRUM project, an integrated project in the field of photovoltaics that integrates various approaches for the better use of the radiation spectrum into one project (III-V multijunctions, thermo-photovoltaics, intermediate band cells, molecular concepts); Here, efficiencies of up to 40% are being sought for.

SOLAR MODULES AND BUILDING INTEGRATION

Building-integrated installations still represent the most important area of photovoltaics use in Switzerland. While low-cost solutions for flat roof applications still dominate the "solar stock exchanges", work is still being done on the reduction of the costs of solutions with a stronger integration aspect. Since a series of systems for mounting installations on buildings has been successfully implemented in the meantime (see section on P+D), development efforts now address the solar modules themselves to a greater degree.

ELECTRICAL SYSTEM ENGINEERING

The main focus in system engineering generally concerns the quality assurance of components (modules, inverters), systems (design, energy production) and installations (long-term observation). The findings in these application-close areas are - especially in a rapidly increasing market - of great importance for the safety, reliability and energy production of future plant as well as for the standardisation of products.

In 2005, the LEE-TISO at SUPSI continued its test measurements on solar modules as part of the Centrale LEEE-TISO 2003-2006 project. This lab, with its class A solar simulator certified for measurements in accordance with ISO 17025, was subjected once more to an annual audit and was able to confirm its accuracy of ±1%. Comparative measurements with other certified labs in Europe (ESTI-JRC and ECN) were carried out and an international Round Robin test of solar modules co-ordinated by the NREL was continued. For thin film modules, the lab now has a new procedure that takes spectral deviation (spectral mismatch) into consideration.

The LEE-TISO is partner in the EU's PV Enlargement project, a Europe-wide demonstration project with 32 installations in 10 countries (5 of them in Eastern

Europe) with a total power of 1.15 MWp. At the end of 2005, a total of 20 of these plants with a total power of 860 kWp were in operation.

At the photovoltaics lab at the University of Applied Science in Burgdorf, the photovoltaics system engineering PVSYTE project was continued. A new 3·5 kilowatt AC/DC source was integrated into the test programme for inverters; it permits research to be carried out into the behaviour of inverters when unusual network states prevail (over-voltage and under-voltage, strong mains-born remote-control signals, over and under-frequency, etc.). In the part-project concerning the long term behaviour of PV installations, the collection of fault statistics that has been going on since 1992 was continued. Further intensive long-term measurements on the Newtech (thin film cells), Mont Soleil and Jungfraujoch installations were carried out. At the latter site a new record yield of 1537 kWh/kWp was noted for 2005

Solaronix is involved in the EU's EURO-PSB project on the development of a polymer solar battery. This is a small, self-charging battery system for mobile applications. The principle is based on the combination of a novel polymer solar cell (organic solar cell) and a rechargeable lithium-polymer battery.

SUPPLEMENTARY PROJECTS AND STUDIES

The LESO at the EPFL is involved in the EU's SUNtool project that is developing a general modelling tool for use in sustainability projects in the urban context. Typically, the tool is to be able to represent a group of buildings or even a whole quarter (<1 km2) from the energetic and materials-flow points of view.

Enecolo is involved in the EU's PVSAT2 project. In this project, satellite-supported performance monitoring has been further developed. More precise satellite data are employed, whilst, on the other hand, the production data of the PV plants are registered centrally. In the year under review, Enecolo focused efforts on the error-detection routines (PV plant faults) developed as part of the PV-SAT process. For the commercial implementation of the project's findings, Enecolo has, together with Meteotest, developed a new service called SPYCE.

With the aid of an inter-departmental platform (seco, DEZA, BUWAL (new: BAFU), BFE) for the promotion of renewable energy in international co-operation REPIC, the CUEPE is developing a module for the PVSYST photovoltaics software, which simulates photovoltaics-driven water pumps.

Within the framework of the EU's integrated FULLSPECTRUM project, the Paul Scherrer Institute PSI is involved in international work on the subject of thermo-photovoltaics (TPV). On the basis of earlier projects, PSI is working on the system-technical aspects of a gas-fired test system as part of the module on thermo-photovoltaics.

The symbolic SOLARIMPULSE project initiated by Bertrand Piccard and various partners was continued in the year under review. The aim of this project is the uninterrupted circumnavigation of the globe with an aircraft powered solely by photovoltaics. The project is a great challenge as far as materials and design is concerned and, in particular, with respect to the supply of energy and energy management under extreme conditions (e.g. UV-radiation, moisture, temperature,

frost, ageing, mechanical vibration). The technical concept was developed in 2005. According to the current state of work, the aircraft will have a wingspan of 80 m, 220 m2 of wing surface, a weight of around 2 t, a wing loading of 8 kg/m2 and approximately 40 kWp of PV power. The 24 motors will average 10 kW over 24 hours. The aircraft is to climb to 12'000 m during the day and cruise slowly down during the night.

See also

Photovoltaic Programme Edition 2006, Summary Report, Project List,
Annual Project Reports 2005 (Abstracts)
June 2006, NET Nowak Energy & Technology Ltd.
www.photovoltaik.ch

2.5 Public budgets for market stimulation, demonstration / field test programmes and R&D

Table 2 Budgets (in Millions of CHF) for R&D, demonstration programmes and market incentives.

	R & D	Demo/Field test	Market
National/federal	9,9	0,2	0,3
State/regional	4,0	0,1	1,4
Total	13,9	0,3	1,7

The Swiss Confederation runs a system of global grants to cantons. Not all Cantons have the appropriate legislature to augment and distribute these funds, and the situation concerning grants for RD&D and market incentives varies greatly. Some cantons set their emphasis on market measures (from marketing events over investment incentives through to direct subsidies), others on installing their own PV demonstration installations or on the support of local “solar stock-exchanges”.

The figure on the level of regional funding for market promotion quoted is the sum of those figures given for 2005.Among 26 cantons only 11 have subsidy schemes for PV.

Besides direct subsidies there are still some solar stock exchanges in operation. The utility of Geneva (SIG, Service industriel de Genéve) contracted in 2005 more then 700 kW of PV besides there own installation of 1 MWp.

3 Industry and growth

3.1 Production of feedstocks, ingots and wafers

There is no production of feedstocks and wafers in Switzerland reported.

3.2 Production of photovoltaic cells and modules

The following table provides a quick overview of PV module production in Switzerland for 2005.

Table 4: Production and production capacity information for 2005 for each module manufacturer

Module manufacturer	Technology (sc-Si, mc-Si, a-Si, CdTe)	Total Production (MW)		Maximum production capacity (MW/yr)	
		Cell	Module	Cell	Module
1 Solterra SA	sc-Si	-	See note	-	N/A
2 SES, Société d'Energie Solaire SA	sc-Si	-	See note	-	N/A
3 Swiss Sustainable Systems	sc-Si and mc-Si	-	See note	-	N/A
Thin-film manufacturers					
1 VHF Technologies SA (Thin Film)	a-Si	See note	See note		N/A

Notes on manufacturers:
No.1: Solterra SA produces a range of PV cells and modules as well as large-format roofing "tiles". Figures on production are not available.

No.2: SES, Société d'Energie Solaire SA, based in Geneva, produces and sells the "SUNSLATES", "SUNWALL" and "SUNSHADE" lines – standardised building elements for roofing and facades- as well as customer-specific modules. Figures on production are not available.

No.3: The 3S Swiss Sustainable Solutions company produces custom laminates up to sizes of 2 x 3.5 m using bought-in cells laminated onto glass. Also, appropriate roof and façade-mounting systems are developed and sold. Production only on a pilot line scale.

No.4: VHF Technologies produces thin-film amorphous cells on plastic foil (polyimide) substrate (Brand name "Flexcells"). Initial applications are in small electronics applications and various products are commercially available, including a charger for portable phones that can be rolled up. A pilot line for larger foil-modules is in operation, production figures are confidential.

Module Prices during the period 1992 – 2005

We are unfortunately not able to quote complete figures for module prices during this period.

Table 4a: Typical module prices for a number of years in CHF (crystalline silicon)

Year	2004	2005
Module price(s): large quantities (500 kWp) -> average	4.30	4.80
Module price(s): large quantities (500 kWp -> Best price	4.10	4.60

3.3 Manufacturers and suppliers of other components

Most success was achieved in the fields of manufacturing and subcontracting,. Some manufacturers defended their top positions in the international market. On account of the export ratio, which increased once more, it was easy to be seen that further progress along the path of becoming a quite normal industry was being made. This meant that, in particular, fewer complete components and devices were produced and that OEM manufacturers are producing to specification. Companies now just focus on their kernel processes in-house and, apart from providing support, only market their complete products.

In the following, the most important manufacturers and subcontractors of auxiliary components are briefly presented for certain areas of work:

a) PV inverters (for stand-alone and grid-connected systems)
The first company that has to be mentioned here is the Sputnik Engineering AG company - on account of its sound development.. For a couple of years now, the company has now been number 3 in Europe as far as its share of the mains-connected inverters market is concerned. In 2005, the company produced inverters with a total rated output of 105 MW. At the end of 2005, the company employed about 55 workers directly and just as many at various subcontractors in Switzerland. The average unit price for PV-installers fell from around 0.60 €/W in 2000 by almost 20% to somewhat less than 0.50 € per watt at present.
Further manufacturers of repute - yet with less business volume - are Studer Innotec in Sion and ASP in Laupen ZH. Both produce automatic charging controllers as well as inverters for island operation. In earlier years Hardmeier Electronics AG and LEC Leutenegger Energie Control also produced inverters; today, they only assure after-sales-service.

b) Storage batteries
Two companies in Switzerland still produce accumulators that can also be used as solar batteries: These are Levo Batterien AG in Dietgen and Saentis J. Goeldi AG in Ruethi in the St. Gall Rhine valley. In particular, the increasingly important role played by OEM products can be clearly observed in this area. For example, the manufacturer Varta belongs to Johnson Control and sells the same products, simply with another label.

c) Battery charge controllers
As already mentioned under a), the main company operative in this area is Studer Innotec in Sion. There are certainly a number of other companies which produce automatic charge controllers in small and smallest series. They are not, however, decisive players in the total market.

d) DC switchgear
The QDC protective power relay manufactured by ABB Normelec AG in Zurich (known formerly under the name of CMC in Schaffhausen) has been part of the delivery program for 15 years now and is still produced in Switzerland. Next year it is to be replaced by a new product.

e) Supporting structures
As stated in the introduction, certain areas of the PV business are becoming a "normal industry". This applies above all to the field of mounting systems. The most installation and marketing companies have subcontractors produce mounting systems for flat roof, facade and sloping roof applications according to their specifications. The Ernst Schweizer Metallbau AG in Hedingen must be mentioned in this respect as an important supplier of parts for several module manufacturers. Plants with a peak power of between 11 and 13 MW have been implemented up to now using the company's Solrif integration system.

f) Manufacturing equipment
In the production equipment field, there are a number of manufacturers of repute who have excellently positioned themselves in the international market. The list begins with two manufacturers of precision wire saws for silicon blocks, the companies Meyer & Burger AG in Steffisburg and HCT Shaping Systems SA in Lausanne.
Module production equipment is manufactured by the companies 3S Swiss Solar Systems AG (Laminators) in Lyss and Unaxis (Thin films) in Pfäffikon SZ.

Measuring equipment is made by the Belval SA in Neuchatel which is often used in module manufacturers' production lines.

All these companies hold top rankings as a result of their continuing innovation or are even expanding in that they are profiting from booming markets in Europe, the USA and, above all, the Far East.
g) Various
A whole series of companies are active and successful in the market. For example, in the field of simulation software, the companies Meteotest AG (Meteonorm) in Berne and the university institute CUEPE in Geneva (PVSYST) can be mentioned in this category. In co-operation with the Meteotest AG, the engineering company

Enecolo AG in Moenchaltorf launched their “Pepper & Spyce” satellite-supported monitoring system for PV plants.

As far as other manufacturers are concerned, the two companies Multi-Contact AG near Basel (plugable connectors) and Huber & Suhner AG in Pfaeffikon (solar cables) are to be mentioned in particular. Both took their chance at an early stage. As a result, in the past few years they were able to profit from their good starting position.

3.4 System prices

Table 5: Turnkey Prices of Typical Applications

Category/Size	Typical applications in your country and brief details	Current prices per W in CHF
OFF-GRID Up to 1 kW	week-end chalets and alpine huts	15.0 – 20.0
OFF-GRID >1 kW	Alpine dairy farms	12.0 – 15.0
GRID-CONNECTED Specific case	Residential, 2-4 kW, roof-mounted system	10.0
GRID-CONNECTED Up to 10 kW	Demonstration projects on public builings	8.5 – 11.0
GRID-CONNECTED >10 kW	“production plants” mostly on flat roofs for solar stock exchange schemes	7.2 - 9.0

Prices exclude sales tax. The figures are estimated on the basis of data provided by engineering offices and consultants involved in the building of PV installations.

Table 5a: National trends in system prices for on-grid standard installations
(Prices in CHF / W for 10 - 20 kW flat roof and 3 to 4 kW residential systems)

YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
10-20 kW	13.00	13.00	12.50	11.80	11.00	10.40	10.20	10.10	9.90	9.40	9.20	8.40	7.50	8.5
3-4 kW	13.40	13.30	13.20	12.80	12.60	12.30	12.30	11.90	12.50	12.20	11.00	9.25	9.10	10.0

3.5 Labour places

No exact figures are available for the number of persons employed in the PV area. The following figures are an estimate based on installed power, imports and budgets for research and development in 2004.

Category	R&D	Cell / Module Manufacturing / Inverters	Planning / Installation	Manuf. facility suppliers	Total
Labour places	around 150	around 300	around 150	around 200	around 800

There was a overall increase in labour places in Switzerland due to the strong world market. Mainly equipment manufacturer like Meyer & Burger (wire saws), 3S (laminators) etc. had a very high production increase.

3.6 Business value

The total end financial value of PV plant installed is estimated at around CHF 35 Million. This is estimated on the basis of PV power installed in 2005 and average turn-key prices.

As practically all cells and the greater part of PV modules in Switzerland are imported, the added value figure is probably more interesting: This amounts to around CHF 15 million.

The value of business for the inverters manufacturer is much higher. One company, Sputnik Engineering, produced inverters in Switzerland with a total yearly capacity of about 105 MW, most of which were sold in Germany. At a price for the inverters of around CHF 0.45 to 0.70 per Watt, this is equivalent to a turnover in Switzerland in the region of 48 to 75 million Swiss Francs.

Table 6: Value of PV business (CHF)

Sub-market	Capacity installed in 2005 (kW)	Price per W (from table 5)	Value	Totals
Off-grid domestic	120	14	*1 680 000*	
Off-grid non-domestic	30	16	480 000	
Grid-connected distributed	2 800	9	25 200 000	
Grid-connected centralized	1 000	8	8 000 000	
				35 360 000
Export of PV products (estimated)				285 000 000*
Change in stocks held (estimated)				-
Import of PV products (estimated)				20 000 000**
Value of PV business				300 000 000

* Inverters, BOC components, manufacturing equipment
** Panels, BOC components

4 Framework for deployment (Non-technical factors)

4.1 New initiatives

Federal Electricity Supply Act
On 3 December 2004 the Federal Council approved its Bill to Parliament concerning the revision of the Federal Electricity Act and the draft of the new Federal Electricity Supply Act. By proposing a flexible, two-stage solution for the liberalisation of the electricity market, the Federal Council set out to satisfy the concerns expressed by the Swiss electorate in its rejection of the proposed Electricity Market Act. Since there is an urgent need for regulation in the area of cross-border transmission, the Federal Council is proposing an interim solution to be brought in ahead of the new law. And in order to promote hydropower and the use of renewable energy, for the first time it is also proposing energy policy objectives and a clearly defined procedure.
The two drafts are currently in the hands of Parliament.
The first chamber decided in September 2005 to introduce an feed in tariff system for all new renable energy sources including PV. Funding for this scheme is generated from a levy on the electricity transmitted on the the Swiss high voltage grid.
The second chamber will discuss this proposal in September 2006.

4.2 Indirect policy issues

Electricity labelling
The introduction by the Federal Council of a labelling requirement for electricity means that, as of 2006, all suppliers will have to provide their clients with details concerning their energy mix. This enables end consumers to evaluate their electricity supply on the basis of qualitative criteria.
Suppliers are required to provide the following details: proportions of energy sources, and origin (i.e. production in Switzerland or abroad) of electricity supplied to all end consumers in the past calendar year. This declaration has to be submitted at least once a year, either on the electricity bill or in the form of an enclosure.

4.3 Standards and codes

The integration of the new IEC standard 60364-7-712 for PV installations in Swiss national electrical installation standards was the subject of work continued in 2005.

Within the framework of the EU co-ordination, various projects (PV-EC-NET, PV-NAS-NET and PV-ERA-NET) analysed the PV programmes in EU countries as far is research, technology development and promotion issues are concerned. These projects aim at a more intense co-operation among European PV RTD programmes in he context of the European Research Area (ERA).

5 Highlights and prospects

Over the past years, industrial activities in the area of solar cells, solar modules and manufacturing equipment have considerably increased. In the inverter area, some products have achieved a high export rate. The Sputnik Company produces grid-connected inverters at a capacity of 105 MW/year and presently ranges as number 3 in the European market. The Studer Company produces stand-alone inverters and is also very successful in exporting.
On the PV industry supply side, different products count among the world leaders, e.g. for wire-sawing machines from HCT as well as from Meyer & Burger; and measuring equipment for PV module manufacturers from Belval. In addition to the solar plugging systems made by Multicontact, another company, Huber & Suhner, has entered into this market. The Alustand® and SOLRIF® mounting systems for building integrated applications have been very successful on the market.
Sarnafil, which has developed a flexible, water-tight flat roof PV system based on thin film silicon solar cells, is taking part in a joint venture with the American company Solar Integrated Technologies (SIT)
As indicated above, industrial activities evolve in the field of process equipment (Unaxis Solar) and small scale products based on thin-film technology (Flexcell from VHF-Technologies, FLISOM). Furthermore, Swiss Solar Systems (3S) is building some of the world's largest PV module laminators. 3S has established a strategic cooperation with the German company Schmid and is the first Swiss manufacturer dedicated solely to photovoltaics which has gone public in 2005.

FUTURE OUTLOOK
Regarding photovoltaic technology in Switzerland, the broad support of the national PV programme can be expected to continue with an ever-increased focus on industrial developments, new products for niche markets and ongoing international involvement. For solar cells and modules, the effort to bring Swiss technology to the market place will continue. Efforts in the technology development will concentrate on market oriented approaches and continuous quality assurance. In the near term, PV market implementation will continue to depend on the initiatives of regional authorities and even more on those from the private sector, namely the utilities. A market volume of about 2,0 to 3,0 MWp/year can be expected under these circumstances. Depending on the outcome of the political debate during 2006, on the new electricity law, concerning the future promotion of renewable electricity, the situation could change to a more favourable situation by 2008 at the earliest.

Annex A Method and accuracy of data

The Data on PV Installations and plant presented in this report have been collected from federal institutions, manufacturers and their professional associations, engineering and consultancy offices and private and institutional initiators of building projects. Much data is taken from the annual reports of the Swiss Federal Office of Energy.
The Figures presented in this national report come from various sources and exhibit various degrees of accuracy. Key figures such as installed power are correct to about +/- 5%. Data concerning national R+D funding are exact. The figure for regional funding of market-oriented activities and subsidies is the sum on data from the 26 Swiss Cantons.
Price and market figures are based on information provided by manufacturers, and we can therefore not quote any percentages on the accuracy of these data.
As for our own estimates, we have quoted any base data sources and stated any assumptions made directly in the text of the report.

Annex B Country information

1) Retail electricity prices (for "normal" power, i.e. not special quality such as hydropower or solar electricity)

   Household: Varies greatly according to area and utility. Prices typically:
   Low period: CHF 0.09 – 0.10 per kWh
   Peak: CHF 0.18 – 0.22 per kWh

   Commercial / Public institution: Strongly dependent on consumption and regional utility:
   Low period: CHF 0.07 – 0.09 per kWh
   Peak: CHF 0.13 – 0.16 per kWh

   Industry can mostly negotiate electricity prices depending on demand / supply situation and own power production.

2) Typical household electricity consumption (kWh): Around 5 400 kWh per household in the year 2004. Households account for approx. 30% of Swiss electricity consumption in 2004.
   Total per capita electricity consumption in 2003: 7 440 kWh

3) Typical metering arrangements and tariff structures for electricity customers:
   - Day-rate and off-peak tariffs for households.
   - Special tariffs for interruptible supply (eg for heat pump installations)
   - Net-metering for domestic PV installations
   - Special rates for trade and industry as well as for large-scale consumers

4) Average household income: CHF 105 000

5) Typical mortgage interest rate: 3%

6) Voltage (household, typical electricity distribution network): 230V ac

7) Electricity industry structure and ownership: Heterogeneous with both vertically integrated and separate generation, transmission and distribution. Both municipal and state owned as well as private organisations are involved. Trend toward liberalisation and privatization. An electricity industry regulator is planned. Approx. 75% of the utilities are public owned.

8) price of diesel fuel (NC) 1.70 CHF

9) Typical values of kWh / kW for PV systems in parts of your country: 850 – 950 kWh/kW for central plain. Higher in mountainous areas and in southern Switzerland.

(Sources: Swiss Statistical Yearbook, Swiss Federal Office of Energy, Association of Swiss Electricity Utilities, individual utilities, Swiss Solar Power Statistics)