International Energy Agency

Co-operative Programme on Photovoltaic Power Systems

Task 1
EXCHANGE AND DISSEMINATION OF INFORMATION ON PV POWER SYSTEMS

National Survey Report on PV Power Applications in Switzerland 2004

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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 Tasks (research projects / activity areas) is the responsibility of Operating Agents. Information about the active and completed tasks can be found on the IEA-PVPS website www.iea-pvps.org. A new task concerning PV hybrid systems is now being developed.

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

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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 2004. 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/m^2, cell junction temperature of 25^{o}C, 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 in households and villages that are not connected to the utility grid. Usually 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 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 centralised PV power system: Power production system performing the function of a centralised 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.

NC: National Currency

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.

1 Executive summary

In 2004, the Swiss photovoltaics market had to cope with unfavourable conditions as far as promotion was concerned. As part of the Swiss government's savings programme the pilot and demonstration (P+D) programme was stopped - several projects were still worked on according to plan, though. At the same time, the world-wide photovoltaics market continued to boom thanks to large-scale promotion and attractive remuneration for solar power. Progress was still being made, however, both in the research and development areas. In spite of difficulties in the P+D area, the number of projects and funding in the Research and Development area could be held reasonably constant as a result of support by European projects, the Federal Office for Education and Science and the Swiss Commission on Technology and Innovation. Considerable differences in PV promotion are to be noted in various Swiss regions. Certain Cantons actively support measures in the energy-efficiency areas and PV projects in particular. Others have stopped support for PV installations altogether. Thanks to the marketing activities of several utilities in the "green power" area, solar power is being sold to electricity consumers. The PV power is both bought in from independent producers and private households as well as being produced in utility-owned installations. In spite of reductions in the important P+D area, the transfer of new technologies from academic institutions to commercial enterprises did carry fruit in 2004, particularly in the thin-film area.

Installed PV power

In spate of the funding difficulties mentioned, total installed PV power in Switzerland rose once more in 2004 and reached a total of around 23.1 MW of which around 20 MW was delivered by grid-connected installations. The increase in total installed capacity was approximately 2.1 MW, of which 2 MW was on-grid. The yearly production figure for the on-grid installations was about 15 700 MWh. As far as the off-grid, stand-alone market is concerned, it is estimated that a total of somewhat more than 3 MW of PV power is now installed in Switzerland, this being an increase of 0.1 MW compared with 2003.

Costs & prices

Lower prices for turn-key PV Installations can be noted as world-wide production and market volumes increase. The average price of installed power for grid-connected, single-family home plant fell slightly to an average of around CHF 9.00 per watt (2003: CHF 9.25). Larger installations with installed powers of over 10 kW, fell more sharply from CHF 8.40 in 2003 to an average of around CHF 7.50 per watt in 2004. Depending on location and mounting technology (flat and sloping roofs), prices for larger installations can be as low as CHF 6.00 per Watt.

PV industry

As far as solar cell production in Switzerland is concerned, emphasis in the area of micromorph silicon and other thin-film cells remained on the transfer from laboratory-scale production technology to industrial scale manufacture. Co-operation continued between a major Swiss manufacturer of equipment used in the production of LCD computer displays and the Institute for Microelectronics in Neuchatel with the purpose of adapting and further developing thin-film coating technology for use in the production of solar cells. For this purpose, a new business unit and subsidiary was founded. Also, first product lines featuring portable, flexible cell-based products were on the market, with new production facilities starting up in 2004. Also, tests were continued on a first application of flexible thin-film modules combined with traditional flexible roofing membranes. The technology has since been transferred to the USA, where such roofing systems are now on offer. Other industrial activities feature the recycling of silicon production wastes by a Swiss company that is successful in the production and sale of wire-cutting machines for semiconductor wafers.

Budgets for PV Promotion

Cutbacks in the promotional funding for PV installations by the Swiss Confederation decided on in 2003 have in 2004 taken effect, in particular in the pilot and demonstration (P+D) project area. This meant that, in 2004, no new P+D projects were supported by funding from the Swiss Federal Office of Energy. This fact is to be much regretted, as an important link in the process of transferring solar technology from the research labs to industrial production has effectively been cut. In 2004, 35 P+D projects were, however, still active - though their number was down to 25 by the end of the year. A total of around CHF 1,5 million was made available for the remaining P+D projects. In the R&D and technology area, Federal funding via various channels amounted to around CHF 11 million. At the local and regional level, subsidies for PV are only available in certain areas.

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. Several combined PV / noise barrier installations along motorways and railway track form an exception to this rule. 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). Systems that combine PV with diesel generators or small hydro installations form the exception to this rule and are used for the operation of farm buildings in remote alpine areas.

In 2004, work on PV Technology was characterised by its orientation towards the research work and the transfer of know-how from research institutions to industry. Know-how-transfer and up-scaling of new technologies remained the most important activities in the thin-film cell area. In 2004, 76 projects were being worked on at Swiss technical institutions and in industry. 35 of the projects were P+D projects still active after government funding cut-backs terminated work in this area.

Several Swiss technical institutions are active in the monitoring and quality assurance areas for both PV components and system technology. Quality assurance and energy yields of various types of PV modules and inverters and the long-term behaviour of grid-connected PV plant are being looked within the framework of the pilot and demonstration projects that are still running.

2.2 Total photovoltaic power installed

Our assessment is based on the following data:

- On-grid PV: Swiss Federal Office of Energy / Swiss Association of Electricity Enterprises, PV Statistics 2004
- Off-grid PV: SOLAR (Swiss Professional Association for Solar Energy) annual survey of PV sales for 2004.

Table 1 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
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*
off-grid non-domestic	70	100	112	143	162	184	190	200*	210*	220*	230*	260*	290*
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**
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
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

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

** This figure includes part of the new installation on the Stade de Suisse Stadium in Bern, which was installed in Winter 2004 / 2005.

Compared with 2003, cumulative installed power increased by around 10%. In spite of the unfavourable political situation concerning the promotion of solar power, the installation of larger PV plant for a "solar stock exchange" led to a considerable increase (see above).

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 W to 150 kW.

2.3 Major projects, demonstration and field test programmes

In 2004, a total of 35 PV pilot and demonstration (P+D) projects were still active. As a result of the Swiss government's plans to cut back expenditure, no new funding of P+D projects was possible in 2004. By the end of the year only 25 projects were still active. Thus, the one-to-one testing of new technologies and components in pilot installations is declining. This important link between research and development and the commercial deployment of new technologies has now been cut and will undoubtedly have a negative effect on the market.

Luckily, other means are available to help continue the demonstration and promotion of solar technology, in spite of the cut-backs in government funding. The so-called "solar stock exchanges" in which solar power is produced and sold to persons and institutions interested in purchasing clean electricity, are proving to be a mainstay in the promotion of photovoltaics in Switzerland. As a result of the opening of the Swiss electricity market, traditional electricity utilities are becoming more open to "alternative" sources of electricity and the needs and wishes of their customers. This has resulted, for example, in the Bernese power utility BKW installing a large-scale PV power generation facility on the roof of the new "Stade de Suisse" football stadium in Berne. In 2004, an initial 850 kW of photovoltaic power was installed. The power produced is sold separately as "1to1" solar power to customers who are willing to pay a higher price for it. The installation will be augmented to produce a total of 1300 kW of peak solar power as customer demand increases.

An almost perfect example of how P+D projects have been able to support and provide aid to Swiss companies in the photovoltaics business in the past is to be found in the development of the "Solarmax" series of inverters. Based on research by the University of Applied Science in Bienne, the Sputnik Engineering company was able to develop prototypes and test them 1:1 in practical use. The company's inverters are, today, well established in the European market. With around 90 MW of installed capacity, the yearly production of inverters is orders of magnitude higher than the whole Swiss PV power that is installed per year (about 1.6 MW).

Another example of successful products originally supported by the Swiss P+D programme is the "SOLRIF" roof-integration frame developed by the Schweizer Metalbau and Enecolo companies. Since the market introduction of this product, mounting frames for almost 10 MW of installed power have been delivered to the European market.

The remaining P+D projects still running in 2004 mainly covered building integration aspects. The testing of new components for the integration of PV systems in building materials was the subject of three P+D projects still running in 2004.

Combining traditional flat-roof waterproofing membranes and flexible amorphous thin-film solar cells, a 15.4 kW flat-roof installation in southern Switzerland delivered important experience and data. The installation's yield of 1 070 kWh/kWp was above expectations and confirms the optimal planning of this installation. The technology used is, in 2005, being marketed in the USA by the partner companies involved.

In the building integration area, the results of two years of measurements made on systems that combine various types of thin-film modules with thermal insulation were pleasing. Detailed results are to published in a final report.

Interesting results have been obtained from the 62 kW multifunctional PV roofing project in central Switzerland. On the roof of a high-bay warehouse, elements are being used that combine thermal insulation and “PowerGuard” modules.

Among the other P+D projects still running or completed in 2004 were the following:

The demonstration of the use of roof-integrated PV is provided by several projects dealing with module mounting systems. In particular, systems that do not cause additional roof loading , i.e. either combine the PV elements with insulation or use the existing gravel on flat-roofs to anchor the panels, are described. Also some of the demonstration plant provide public displays of the power being produced, as for example, on the customs’ building at the Swiss border town of Kreuzlingen.

In the area of stand-alone systems, a P+D project was continued that is investigating the use of a combined PV and fuel cell driven energy supply system for locations in remote areas with no conventional electricity supply.

On-going measuring and monitoring projects in 2004 included a facade-mounted, 80 kW PV installation which is being measured and analysed in Wittikofen near Berne, Monitoring of tests being made in Zurich on various thin-film modules and measurements made on the recently refurbished 100 kW installations along the motorway near Chur and along a railway line in Southern Switzerland.

In the motivation area, a study was continued on how to improve the implementation of building-integrated PV systems by the reduction of hindrances, improvement of information and increasing the level of professional competence of planners, investors and property developers. The integration of the new IEC standard 60364-7-712 for PV installations in Swiss national electrical installation standards was also the subject of work continued in 2004.

In the alpine resort of St. Moritz, measurements were continued on 9.7 kW PV installation on the lower Piz Nair cableway station in addition to the company’s existing 17.8 kW and 13.5 kW PV installations in the area. Interesting results on albedo effects in Winter and Spring have been collected.

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 2004. As a result of cut-backs in government funding, no new P+D projects were started in 2004

Project Date plant start up	Technical data/Economic data	Objectives	Main accomplishments until the end of 2004 /problems and lessons learned	Funding	Project management	Remarks
Stade de Suisse: Sport and Event Arean in Berne, 2004/5	850 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. Informs the public on solar power	The installation was completed in late 2004, the official inauguration took place in 2005	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	Waterproofing membranes mounted in August 2003. Similar, plastic foil-PV technology is to be marketed in the USA	Private, SFOE	SUPSI, DACD, LEEE-TISO, Cannobio	3 small open-rack installations with a-Si and c-Si for comparison
Corviglia and Piz Nair alpine PV, St. Moritz, 2003	Monitoring of the performance of PV plant mounted on aerial cableway stations	Monitoring the performance of PV installations mounted on the facades of the stations and along the track of the Corviglia funicular	The expected increased power production due to albedo effects was confirmed	Private, SFOE	Sun Technics, Küsnacht	Plant on the lower station of the Piz Nair cableway inaugurated in July 2003
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	Planning accomplished, roofing mounted December 2003	Private, SFOE	Zagsolar, Kriens, Trisa Electro AG, Triengen	Production display to be mounted on nearby transformer station.
Thin-film test installation, Migros, Zürich, 2002	Comparison of 6 types of thin-film modules, each in 3 application modes	Direct, long-term comparison of various types of commercially available thin-film modules. Conventional sc-Si for comparison	Measurements show that some cells without back-ventilation or mounted on thermal insulation are not detrimentally affected by high temperatures	SFOE, EWZ, private (solar stock exchange	Energiebüro, Zürich	Mounting variants: flat, thermally insulated; flat, open back; inclined, open back.

				project)		

2.4 R&D Highlights

In Switzerland, a wide variety of research and development projects deal with solar cells in spite of cutbacks in national funding that were becoming noticeable in 2004. Thanks to support from other academic and governmental institutions as well as industrial co-operation projects, both fundamental research as well as technology transfer tasks were worked on in 2004.

Thin-film silicon cell concepts continued to be an important area in Swiss photovoltaics R&D, with much work being done at the University of Neuchatel (IMT), the Federal Institute of Technology in Lausanne (CRPP), and the Universities of Applied Science in Le Locle (EIAJ) and Buchs (NTB). Industrial co-operation was centred at Unaxis Solar (Truebbach) and VHF Technologies (Yverdon). At these companies, work continues on transferring laboratory-scale production technology to full industrial scale production.

In this area, the Unaxis company is adapting its commercially available deposition equipment originally used in the production of LCD screens for computer monitors and televisions to fit the needs of the production of thin-film solar panels.

Other areas of interest involve the optimisation of thin-film cell efficiency and their production. Various topics continued to be looked at, including the improvement of deposition speed of microcrystalline silicon, the improvement of light-capture (optimal absorption and scattering), the increasing of conversion efficiencies and work on transparent oxide layers (TCO). This work and related tasks concerning substrates and micro-morph tandem cells confirmed the leading position of the Institute of Micro-Technology (IMT) at the University of Neuchatel.

In a new project together with the Unaxis company, a plasma deposition plant is being further developed to allow the fast deposition of micro-crystalline silicon on large-area (1.4 m2) substrates. First tests have produced cells with efficiencies of 5.5% (micro-crystalline cells) and 9.2% (micromorph cells).

The CRPP in Lausanne is also working with Unaxis on a new, large-area VHF reactor for the deposition of amorphous and micro-crystalline silicon cells, featuring plasma-activation frequencies of up to 100 MHz and deposition rates of over 4 Angstroms per second. The NTB in Buchs is also working with Unaxis on the implementation of a spectral response measurement system.

The VHF Technologies company - itself a spin-off of the IMT - worked on optimising the industrial production of thin-film cells on flexible plastic substrates in a roll-to-roll process. First products under the “flexcell” trade-name are already on sale. This company is also doing work together with the IMT on the development of nano-structured optical gratings that are to improve performance of the polymer-based cells.

In the area of crystalline silicon, the HCT Shaping company finished its work as part of the EU’s RE-SI-CLE project looked into ways of recycling the wastes produced in the semiconductor industry for re-use in the production process. The topic of thermo-photovoltaics was looked at at the Paul Scherrer Institute (PSI). The “HEAT” project, which was carried out together with Hoval company, was completed that aimed to investigate the use of silicon cells in a thermo-photovoltaic application to provide power for an autonomous heating unit. The PSI also did work in the framework of the EU's FULLSPECTRUM project.

Long-term work on CIGS and cadmium-telluride cells was carried further at the Federal Institute of Technology in Zurich, where research within the framework of many EU projects was carried out. The FLEXCIM project looked at flexible CIGS-cells. 5 x 5 cm cells on metal and poly-imide substrates were produced. Efficiencies of 10 -12% were regularly attained and a new world record efficiency of 14.1% was attained for a flexible cell on plastic. An anti-reflex coating is to bring this efficiency up to 15%.

The development of dye-sensitised nano-crystalline cells was continued within the framework of Europe's NANOMAX project at the Swiss Institute of Technology in Lausanne. In co-operation with industry, work was done as part of the TOPNANO 21 project on the technical up-scaling of the production of dye-sensitised cells on flexible stainless-steel foil substrates. Efficiencies of 3% were attained.

Work was also carried out at the Institute on a new EU-project, MOLYCELL, that deals with flexible organic and hybrid solar cells. Photovoltaic-active textiles were the subject of a new innovative project.

Dye-sensitised zeolite crystals form the basis of work being carried on at the University of Berne on antenna-solar cells as part of their solar-chemistry programme.

Building integration is still the most important area of PV applications. Whilst the installations serving numerous "solar stock exchanges" look for simple (and cheap) solutions for the mounting of panels on flat roofs, methods of actually integrating PV panels into the building fabric was a topic covered by many P+D projects. Research and development was concentrated on integration aspects; in particular emphasis was placed on the integration of thin-film cells. in facade and roofing elements. Several Swiss companies and institutions are active in this area.

The use of chemically-etched anti-reflex glass for increasing the efficiency of crystalline solar modules continued to be investigated. Another development project, AFRODITE, which involved the production of back-contacted, aesthetically-pleasing crystalline cells, was commercialised earlier than expected. Also, the BIPV-CIS project was launched, which aims to improve the characteristics of CIS cells integrated into roofing and facade elements.

In the development of electrical connections for CIGS cells, the CONSOL project is looking at the use of electrically conducting adhesive tape and ultra-sonic welding.

In the electrical systems technology area, the main emphasis remained on the quality assurance of components (modules, inverters), systems (engineering) and plant (long-term monitoring). The standardisation of both products and testing procedures remains an important topic, since, for example, standards for mounting components in building integration still do not exist.

After the conclusion of the long-term tests on the over 20-year old modules at the LEEE-TISO a new test centre with an ISO 17025-certified laboratory with a class A sun-simulator was inaugurated. A yearly audit showed an accuracy of +/-1% and comparisons with other laboratories were made. The LEEE-TISO is also a partner in the EU's "PV Enlargement" project and looks after measurement calibration activities.

The photovoltaics laboratory at the University of Applied Technology in Burgdorf continued its work in the "PVSYTE" PV system technology project and made considerable improvements in its semi-automatic solar-generator simulator used for testing inverters. Several examples of newer inverters were tested and a substantial improvement in performance noted.

The "Energy rating of Solar Modules" project looked at the determination of performance matrices using different experimental methods. The precision of the results is however not yet sufficient.

In the area of energy storage, work on the development of a polymer solar battery done within the framework of the EU's EURO-PSB project was continued. Here, a combination of a novel organic polymer solar cell and a rechargeable lithium polymer battery is to be used for mobile applications in particular.

Other R&D work covered the development of a general modelling tool for the determination of sustainability and the simulation of energy and material flows for groups of buildings an the urban context. Development work on software for the monitoring of production using satellite data was continued in the PVSAT2 programme. Two projects concerned with the use of satellite environmental data for solar purposes, ENVISOLAR and Heliosat3, were also continued.

Market acceleration using SWOT analysis is the topic of a general EU project called PV-Catapult, in which the LEEE-TISO is taking part. The "Solarimpulse" project carried by Bertrand Piccard and various partners is a symbolically important project that foresees the non-stop circumnavigation of the earth in a solar-cell-powered aircraft. The Federal Institute of Technology in Lausanne is serving as the project's scientific advisor.

2.5 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	Market	Total
National/federal	**11,0**	**1,5**	**0,01**	**12,6**
State/regional	**4,0**	**0.01**	**1.54***	**5,55**
Total	**15,0**	**1,51**	**1,55**	**18,15**

* including grants / subsidies for private persons

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 2004 by 22 of the 26 Swiss Cantons. The actual total may be somewhat higher, as not all figures are available.

Since 2003, the Canton of Geneva supports PV plant installed in connection with the local “solar stock exchange” with CHF 200 000 per year and the Canton’s utility offers interesting remuneration for privately produced solar power and 20-year contracts. The Canton is on the way to reaching its target of installing 5 MW of PV power by 2006.

The City and Canton of Basle’s incentive levy on electricity is continues to provide a very important impulse for PV in the area. The part of the income from this levy that is reserved for the promotion of PV power helped fund 225 kW of additional PV power in 2004, with around CHF 1.3 million being paid out.

3 Industry and growth

There is no large scale industrial cell production in Switzerland. The Unaxis company, with its background in vacuum technology and the production of thin-film coatings (for LCD displays, for example), has, however, continuing to work together with the Institute for Micro-Technology in Neuchatel on adapting and further developing current industrial production equipment for the production of thin-film PV modules. Apart from the research facilities located near the Institute, Unaxis opened a R&D production facility in Trübbach, Switzerland, where 1.4 m2 thin-film modules can be manufactured. First production examples were shown at the Photovoltaic World Conference in Paris.

The VHF Technologies SA, a university -"spin-off" company, is working on the commercialisation of the new thin-film technologies developed at a local University of Applied Technology. In Yverdon-les-Bains, for example, VHF Technologies already produces amorphous cells on polyimide substrates in a continuous, roll-to-roll process.

3.1 Production of feedstocks and wafers

There is no production of feedstocks and wafers in Switzerland. Table 3 is therefore not applicable.

3.2 Production of photovoltaic cells and modules

The following table provides a quick overview of PV module production in Switzerland for 2004.

Table 4: Production and production capacity information for 2004 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 Star Unity (SunnyTile)	mc-Si	-	*See note*	-	N/A
2 Solterra SA	sc-Si	-	*See note*	-	*N/A*
3 SES, Société d'Energie Solaire SA	sc-Si	-	*See note*	-	*N/A*
4 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*

There are no manufacturers of Concentrators in Switzerland.

Notes on manufacturers:

No.1: Star-Unity buys in mono-crystalline cells and integrates them into roof tiles with standard dimensions.

No.2: Solterra SA produces a range of PV Panels as well as large-format roofing "tiles". Figures on production are not available.

No.3: 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.4: 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. Around 55 kW of the company's MegaSlate fully-integrated roofing system featuring CIS cells was installed in 2004.

Thin-film manufacturers

No.1: VHF Technologies produces thin-film amorphous cells on plastic foil (polyimide) substrate. 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 – 2004

We are unfortunately not able to quote complete figures for prices during this period. For the thin-film modules, no price information is available. Table 4a is therefore not applicable

3.3 Manufacturers and suppliers of other components

Table 5 Price of inverters for grid-connected PV applications.

As far as of balance-of-system components are concerned, one of the innovative Swiss companies in the inverter area has, in spite of the reduced impetus in the Swiss PV market, been enjoying success on a Europe wide basis, being now being the third most important inverter manufacturer in Europe. Sputnik Engineering sold, in 2004, over 90 MW of inverter power, most of which to European markets. Compared with a total of only 2.1 MW newly installed mains-connected PV power in Switzerland itself, the figure shows that a Swiss high-technology product whose development was initially supported by a government programme has been successful on an international market.

Another successful market is that of combined inverter / battery-chargers for stand-alone and back-up systems, where the Studer Innotec company grew by 20% in 2004 and sells around 60% of its products for use in solar applications.

In the area of supporting structures and combinations of PV panels / cells with structural elements and materials, several systems developed in Switzerland continued to be successfully marketed in 2004.

Another area in which Switzerland is active is the area of manufacturing equipment for the world-wide PV industry, such as wire-sawing machines, connector systems and measuring equipment. One of these companies, HCT Shaping Systems, is involved in the international market for wire-cutting machines for semiconductor wafers. In particular, the company delivered several systems to the expanding Chinese market in 2004. The company now also offers equipment for the recovery of raw silicon from silicon wastes, thus addressing an important problem in the resource-management of crystalline silicon.

3.4 System prices

Table 5: Prices of typical applications

Category/Size	Typical applications and brief details	Price per W in CHF
OFF-GRID Up to 1 kW	Roof-mounted, chalets, leisure activities, road building-sites (emergency telephones)	16.00
OFF-GRID >1 kW	Roof-mounted, holiday homes, remote homes	14.00
ON-GRID Specific case	3 kW roof-mounted system, single-family home	9.10
ON-GRID Up to 10 kW	Small modular plant (AC-Modules) roof-mounted, private owner	8.90
ON-GRID >10 kW	Commercial and P+D plant around 50 – 100 kW mostly flat-roof mounted, also on noise-abatement structures	7.50

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
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
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

3-4 kW residential systems
After the rise in prices in 2000, caused by tighter conditions on the market for buyers resulting from increased promotional measures in Switzerland's neighbouring countries, the average price for 3 - 4kW residential systems has dropped continuously. In 2004, the decrease in price was only slight and not as pronounced as for larger systems.

Standardised System Kits

Standardised, modular domestic PV systems are available in several varieties including those that can be easily set up by the “man on the street”. These units can be plugged into a normal power socket and require no installation work. With the help of special funding by certain Swiss Cantons, standardised systems for single family homes were marketed successfully in 2004.

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 ManufacturingInverters	Planning / Installation	Manuf. facility suppliers	Total
Labour places	around 140	around 270	around 105	around 50	around 565

3.6 Business Value

The total end financial value of PV plant installed is estimated at around CHF 18 Million. This is estimated on the basis of PV power installed in 2004 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 8 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 90 MW, most of which were sold in Germany. At a price for the inverters of around CHF 0.50 to 0.75 per Watt, this is equivalent to a turnover in Switzerland in the region of 45 to 67 million Swiss Francs.

Table 6: Value of PV business

Sub-market	**Capacity installed *in 2004* (kW)**	**Price CHF/W** *(from table 5)*	**Value (CHF)**	**Totals (CHF)**
Off-grid domestic	70	14.00	980 000	
Off-grid non-domestic	30	16.00	480 000	
Grid-connected distributed	2 000	8.20 *	16 400 000	
Grid-connected centralized	0	-	-	
Total				**17 860 000**
Export of PV products				80 000 000**
Change in stocks held				-
Import of PV products				10 000 000***
Value of PV business				**87 860 000**
Value of Equipment for manufacturing (estimate)				**20 - 50 000 000**

* 1 000 kW at CHF 7.50, 1 000 kW at CHF 8.90
** Inverters, BOC components
*** Panels, BOC components

4 Framework for deployment (Non-technical factors)

4.1 New initiatives

With the current national energy legislation, the responsibility for funding promotion activities in the PV area lies with the Swiss Cantons - and with private industry. Most activities therefore occur at a regional level and vary considerably from region to region. In 2004 no new promotional programmes for PV are to be noted at this level.

In the area of “green electricity” marketing, Swiss labelling institutions and utilities are active in the national and international areas. Certain producers of “green” electricity are attempting to sell their ecological added value - not to be confused with the actual electrical power – to utilities and consumers in the form of certificates for the production of a certain amount of “green” power.

The activities of certain regional electricity utilities in the sale of solar-produced electricity were an important mainstay of Swiss PV effort in 2004. In particular, the Utilities in Basle and Geneva were successful in actively marketing solar power and so helped fund further PV installations in their areas.

An inter-departmental platform was set up by the Swiss government for the promotion of renewable energy in international co-operation (REPIC). NET is responsible for the co-ordination of the work which for example provides the funding for the Swiss contribution to IEA PVPS Task 9.

4.2 Indirect policy issues

As legislature on the liberalisation of the electricity market was refused in public voting in 2002, the various players continued to develop new structures for the electricity industry in 2004. The decree which is to regulate the generation, distribution and supply of electricity in Switzerland and combat the uncoordinated opening of the electricity market was still not in effect. Factors affecting niche markets such as regulations concerning the transport of “green” electricity to customers are also being addressed within the framework of this and other, existing, legislation.

Two advantages for PV power result from the revised Nuclear Energy Law: the remuneration for electricity generated from renewable resources (15 cents/kWh) is now to be paid by the overland grid companies and no longer by the local utilities. Also branding, i.e. the declaration of how the electricity is generated, is also called for by the new legislation.

4.3 Standards and codes, international cooperation

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 2004.

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

In comparison with other countries, the general conditions for the promotion of PV power systems in Switzerland remained poor in 2004. No broad national PV promotion programme exists at the moment and cut-backs in federal funding have affected the P+D area in particular. The promotion of the wide use of PV systems applications is therefore becoming more and more dependent on private initiative and marketing campaigns: basically, PV promotion is now a question of how well "green" electricity can be marketed.

In spite of these difficulties, it has been possible to keep the number of research and development projects and funding fairly constant thanks to support offered by European projects, the Federal Office for Education and Science and the Swiss Commission on Technology and Innovation.

After new electricity market legislation was turned down in 2002, no new programmes have been launched and possibilities for supporting the production of power from renewable resources stays at an all-time low. The possible introduction of levies on the CO2-production of non-renewable energy sources and an idea put forward by the oil industry for a "voluntary" levy on oil, diesel and petrol (the "Climate Cent") could help internalise some of the indirect costs of these energy carriers and provide the basis for promotion of energy efficiency and renewable forms of energy. These issues were discussed in parliament in 2004 but are still not yet finalised.

There is, however, still a positive side to the PV situation in Switzerland: it is expected that industrial interest and investments in the area of the manufacture of thin-film solar cells and modules will continue to increase and thus allow R&D findings to be effectively transferred to industrial products and applications..

In the area of public-oriented PV power plant, a certain amount of effort is being made by power utilities, some of whom support the installation of PV plant in their supply areas.

One of the main highlights in the Swiss PV scene in 2004 was the construction of the new national football stadium "Stade de Suisse" in Berne which is to be officially opened in summer 2005. The stadium boasts the largest building-integrated PV installation in Switzerland. The initial installation covers around 8,000 m2 of the stadium's roof. With around 850 kW rated peak output, the PV plant will deliver power for the local utility's "solar stock exchange". If the sale of "green" power proves successful, it is planned to increase the installed power to 1.3 MW by installing a further 4,000 m2 of additional PV panels on of the stadium's roof.

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 draft 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 22 of the 26 Swiss Cantons. With the shift of responsibility for promotional funding towards the Cantons and even individual municipalities the collection of data has become more difficult. The accuracy of our data in this category is therefore questionable and should be taken as a rough guide with an accuracy of +/- 20%.

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

This information is simply to give the reader some background about the national environment in which PV is being deployed. It is not guaranteed to be 100 % accurate nor intended for analysis. It is recommended that the reader does his or her own research if more detailed data is required.

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 5 000 kWh per household in the year 2000. Households account for approx. 31% of Swiss

electricity consumption.
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 36 600

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) 1.50 CHF

9) Typical values of kWh / kW for PV systems in parts of your country: 815 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)