SWITZERLAND

PV TECHNOLOGY STATUS AND PROSPECTS

STEFAN NOWAK, NET NOWAK ENERGY & TECHNOLOGY LTD.
AND STEFAN OBERHOLZER, SWISS FEDERAL OFFICE OF ENERGY (SFOE)

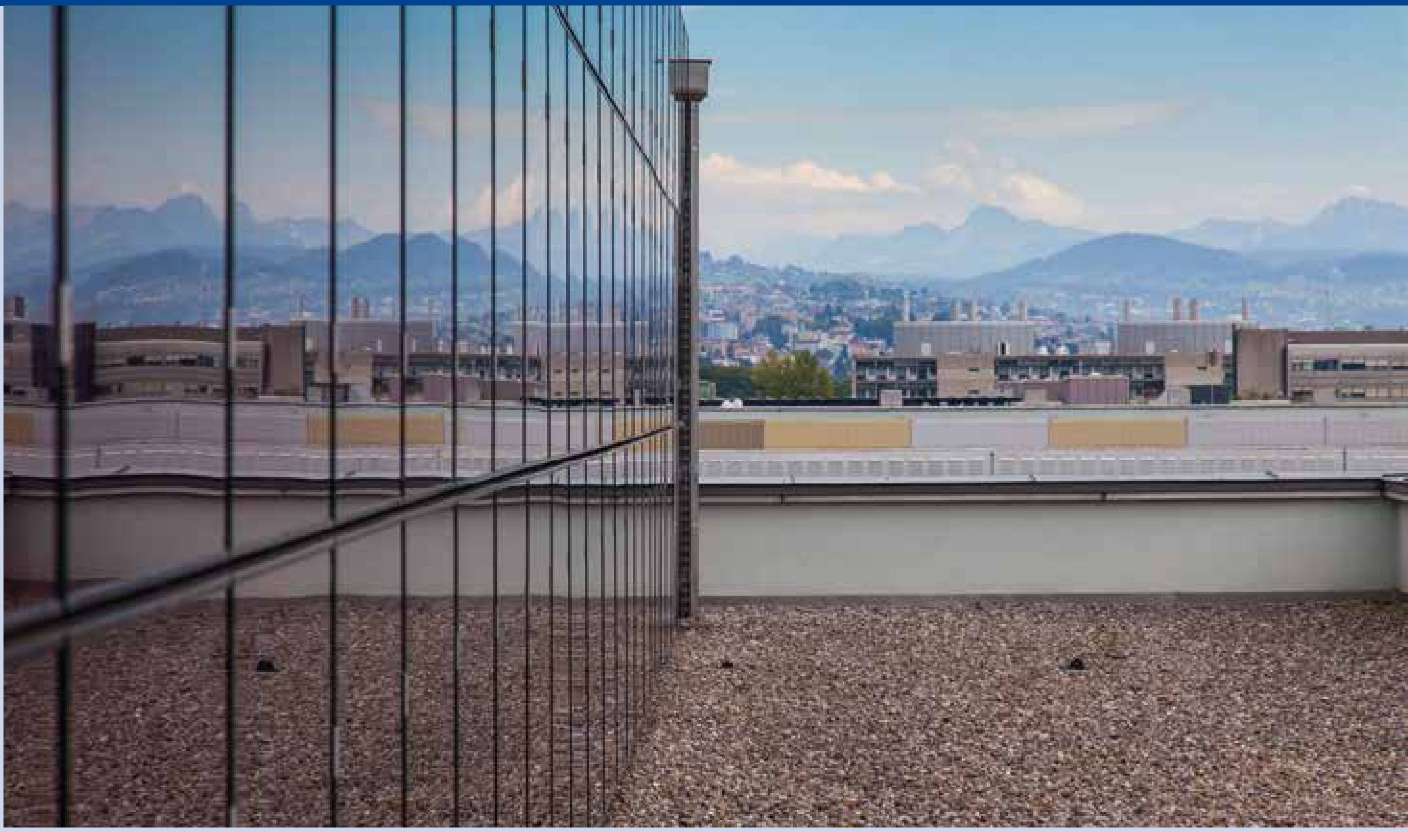

Fig. 1 - PV-façade system on EPFL campus, Lausanne, Switzerland (Photo: © NET Ltd. /DanielForster.com).

GENERAL FRAMEWORK AND IMPLEMENTATION

There is a general consensus in Switzerland that solar photovoltaics will play an important role in the long term future Swiss electricity supply. According to the official scenarios, 10 – 12 TWh should come from photovoltaics by 2050. Compared to the annual national electricity consumption of close to 60 TWh in 2014, this would represent close to 20 % of this value. The Swiss solar industry claims such contributions to be achievable much sooner than 2050 (www.swissolar.ch).

In 2014, on the levels of Swiss policy and administration, work continued extensively regarding the preparation of the various measures in conjunction with Switzerland's phase-out of nuclear energy decided in 2011 in the framework of the new energy strategy 2050. These measures will have impacts on all levels from research to implementation and use, as well as regarding legislative and normative issues. Before coming into force, there will likely be a public vote on the new energy strategy, expected in 2016.

While the final form of the new energy strategy 2050 and its set of policy measures continue to be defined and shaped, a number of decisions have already been made by the national parliament in view of this strategy. These concern, for instance, an action plan for an increased energy research activity throughout all relevant energy technologies. Building on existing research activities, eight new national competence centres for energy research (SCCERs) have taken up their activities during 2014. The goal of these centres is to build up new permanent research and innovation capacities and institutional networks in the different technology areas. Alongside this structural measure, important additional financial means have been invested to support research activities in the different areas on the project level. Moreover, the financial means for pilot and demonstration projects have been further increased, aiming at speeding up the technology transfer from research into industrial processes, products and applications.

On the implementation level, support continues to be provided by an evolving regulatory framework. The deployment of photovoltaic power systems in the short term, namely up to 2016, is governed by a differentiated support scheme. Since early 2014, the following conditions apply: Besides the feed-in-tariff scheme used since 2009 with decreasing tariffs and increasing shares attributed to photovoltaics, systems between 2 and 10 kW now benefit from a onetime investment subsidy and are not supported in the feed-in-tariff scheme any longer. Systems between 10 and 30 kW may choose between the investment subsidy and the feed-in-tariff whereas systems below 2 kW have no support at all at the federal level. Systems of 30 kW and more continue to benefit from the feed-in-tariff as before. As an additional new element, self-consumption of the electricity produced is allowed and accounted for. These measures were also meant to relieve a long waiting list in the feed-in-tariff scheme. However, by the end of 2014,

Fig. 2 - PV systems on different farmhouses, Moosseedorf, Switzerland (Photo: © NET Ltd. /DanielForster.com).

Fig. 3 - 538 kW roof-integrated PV system, Affentranger Bau AG, Altbüron (Photo: © NET Ltd. /DanielForster.com).

more than 35 000 systems were still on this waiting list. The future of the Swiss feed-in-tariff support scheme depends on the decisions on the political level concerning the amount of the levy on the electricity price reserved to finance the feed-in-tariff.

The development of the photovoltaic sector in Switzerland builds on a strong research and technology base, a diversified industrial activity and, more recently, an acceleration of the market deployment efforts. A comprehensive research programme covers R&D in solar cells, modules and system aspects. The Swiss energy research strategy is defined by an energy RTD master plan updated every four years. The master plan developed by the Federal Commission for Energy Research (CORE) in cooperation with the Swiss Federal Office of Energy (SFOE) is based on strategic policy goals (energy & environment, science & education, industry & society) (www.energy-research.ch).

Concerning market implementation, the photovoltaic sector in Switzerland further developed in the year 2014. Following some difficult years going along with the worldwide consolidation within the PV industry, some of the industrial activities show signs of a renewed uptake whereas others continue to face financial difficulties, with some companies abandoning their activities in the PV area. Nevertheless, activities in the Swiss PV supply industry remain high with an increasing emphasis on technology development and innovation. R&D activities in the public sector confirm this increasing trend. Several industrially oriented projects aiming at pilot production facilities were intensified throughout the year. On the technology front, the key competence centres continued their efforts in their respective domains (solar cells, modules and systems) while increasing their cooperation with industry and on the international level.

The support of the national PV RTD programme can be expected to continue with a focus on innovative research activities, rapid technology transfer, industrial developments, new products for niche markets and ongoing international involvement. Due to the strong Swiss currency, global competition for the heavily export oriented industry remains an issue. Nevertheless, the efforts to bring Swiss technology to the market place continue. Efforts in the technology development will concentrate on short to medium term market oriented approaches and continuous quality assurance.

The strategy to promote international co-operation on all levels continued, related to activities in the 7th Framework and the new Horizon 2020 Programme of the European Union, the European PV Technology Platform, the IEA PVPS programme and in technology co-operation projects.

With a strong research base and leading activities in various PV technologies, an ongoing diversified industrial base along the entire value chain, an increasing market deployment activity and an overall favourable policy framework, the signs continue to be positive for an increased role of PV, from research over industry all the way to the market.

NATIONAL PROGRAMME

Switzerland has a dedicated national photovoltaic RTD programme which involves a broad range of stakeholders in a strongly coordinated approach (SFOE PV RTD programme, www.photovoltaic.ch). This national photovoltaic programme focuses on R&D, D in a system and market oriented approach, from basic research, over applied research, product development, pilot and demonstration projects all the way to accompanying measures for market stimulation. On the technical level, silicon heterojunction and different thin film solar cells, their variations and building integration are the topics of highest priority. New concepts such as perovskite solar cells and tandem cells with these are increasingly being investigated. The programme is organised along the entire value chain and addresses the critical gaps from research over technology to the market place. Thorough component and system analysis, as well as testing, aim at increasing efficiency and performance. Accompanying measures to raise the quality and reliability of photovoltaic power systems include work on environmental issues, standards and design tools.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

In 2014, more than 70 projects, supported by various national and regional government agencies, the European Commission and the private sector, were conducted in the different areas of the photovoltaic energy system. Innovative solutions, cost reduction, increased efficiency and reliability, industrial viability and transfer as well as adequate market orientation are the main objectives of the technical R&D. For solar cells, the previous strong focus on thin film solar cells is diversifying with projects in a wider variety of materials

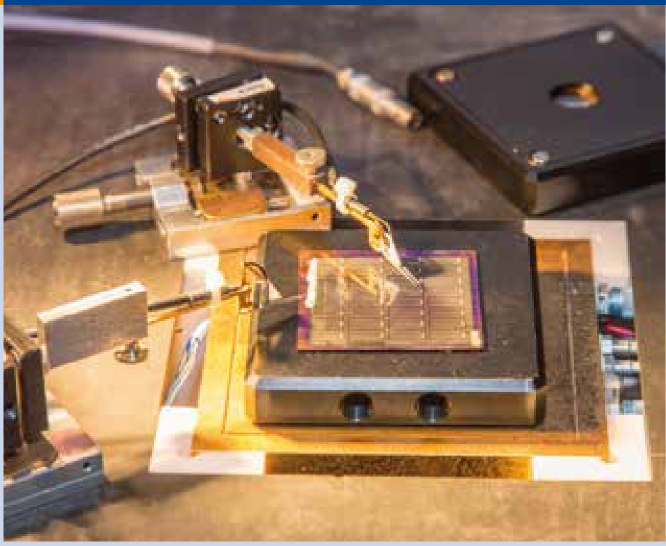

Fig. 4 - CIGS flexible solar cell analysis at EMPA (Photo: © NET Ltd. /DanielForster.com).

Fig. 5 - CSEM Christophe Ballif and Laure-Emmanuelle Perret-Aebi with white and colored PV-modules (Photo: CSEM).

(crystalline silicon, amorphous and microcrystalline silicon, compound semiconductors, dye-sensitised, perovskite and organic solar cells). Work at the Swiss Federal Institute of Technology (EPFL) in Neuchâtel continued on thin film micromorphous solar cells and increased on advanced structures for high-efficiency crystalline silicon solar cells. Further progress is being achieved in the area of high-efficiency heterojunction silicon solar cells, reaching efficiencies up to 22,4 %. On the more fundamental R&D side, a new project on high-efficiency tandem configurations involving perovskite solar cells started in 2014. At the other end, industry co-operation was extended with various companies. The CSEM (Centre Suisse d'électronique et microtechnique), a close partner of the PV-Lab at EPFL, further developed its new photovoltaic technology centre in Neuchâtel. The mission of this PV technology centre is to accelerate the transfer of innovative PV technologies to the industry by an increased collaboration and a dedicated infrastructure.

With regard to CIGS solar cells, the Swiss Federal Laboratories for Materials Testing and Research EMPA continued their work focussed on high efficiency flexible CIGS cells on plastic and metal foils (Fig. 4) . As one of the highlights towards industrial implementation of this technology, a new pilot machine on roll-to-roll CIGS deposition was commissioned in 2014. At the end of the project the pilot machine is ready to demonstrate the transferability of the multistage low-temperature CIGS deposition process from small scale, static laboratory equipment to medium scale, inline equipment with industrial relevance.

For dye-sensitised solar cells, work continues at EPFL on new dyes and electrolytes as well as high temperature stability of the devices. Further rapid progress has been achieved at the Laboratory of Photonics and Interfaces at EPFL concerning perovskite-sensitized solar cells which have reached solar cell efficiency values of 18 % and more. Perovskite-sensitized solar cells thus continue on the path of the steepest efficiency increase in recent years and attract a large interest from the global PV research community.

Organic solar cells are the research subject at the Swiss Federal Laboratories for Materials Testing and Research EMPA, the University of Applied Sciences in Winterthur (ZHAW) as well as at CSEM in the Basel region. In this technical area, CSEM coordinates the large European project, Sunflower.

An increasing interest for photovoltaic technology can be observed at various research institutions as well as from industry. In line with the international trend to a broader scientific and technological base, increased activities take place in the fields of nanotechnology, chemistry and numerical modelling.

On the part of application oriented research, emphasis continues to be given to building integrated photovoltaics (BIPV), both for new solutions involving different solar cells as well as for new mounting systems and structures for sloped roofs and facades. New design options involving coloured PV modules are progressively being developed. In this regard, a highlight of 2014 was the announcement of white PV modules by CSEM (www.csem.ch/white-pv) (Fig. 5). A dedicated website deals with the application aspects of BIPV (www.bipv.ch) and includes information about available products.

As a recent topic rapidly gaining relevance in some countries and regions, grid integration has continued to generate interest and recent projects have extensively analysed the implications of PV on the distribution grid. Methods to considerably increase the share of PV in distribution grids have been identified based on detailed modelling work. Based on these more theoretical studies, new pilot projects have started investigating different approaches and experiences with high penetration PV in various grid configurations. High levels of PV penetration in distribution grids are thus no longer considered as insurmountable barriers.

With the ongoing market development, quality assurance and reliability of products and systems, as well as standardisation, continue to be of high priority. The Swiss centres of competence at the Universities of Applied Sciences of Lugano and Burgdorf carefully evaluate products such as PV modules, inverters and new systems. The test infrastructure (Fig. 6) is continuously expanding and includes the accredited test centre for IEC module certification (Lugano, http://www.supsi.ch/isaac/swiss_pv_module_test_centre.html) as well as the largest solar simulator for inverter testing up to 100 kW capacity (Burgdorf, www.pvtest.ch). Long term experience with the operation of photovoltaic power systems is carefully tracked for a number

Fig. 6 - Spectral Responsivity test lab at SUPSI-ISAAC, Canobbio, Switzerland (Photo: © NET Ltd. /DanielForster.com).

Fig. 7 - 32 000 m² PV system with 5,2 MWp, producing 6,8 GWh per year, Migros, Neuendorf (Photo: © NET Ltd. /DanielForster.com).

of grid-connected systems, ranging between 10 and more than 30 years of operation. Continuous development of system solutions has resulted in a number of industrial products well positioned in the export market.

Work continued on the second prototype of the solar powered airplane SolarImpulse (www.solarimpulse.com) by Bertrand Piccard, André Borschberg and their team. Meanwhile, further flight experience was gained throughout the year with the goal to start the first round the world flight in early 2015.

International co-operation continues to form a strong pillar of the R&D activities with more than 20 projects running in the 7th framework and Horizon 2020 RTD programmes of the European Union during 2014. The co-operation within the IEA PVPS programme has remained a further strategic activity.

Regarding international co-operation within the recent European SOLAR-ERA.NET project (www.solar-era.net) coordinated by Switzerland, first joint projects started in 2014, namely by EMPA on front contacts for CIGS solar cells. In parallel, a second joint call was executed during 2014 covering both PV and concentrated solar power (CSP) which again had a high and more focussed resonance in the research community. The collaboration with the European Photovoltaic Technology Platform (www.eupvplatform.org) continued throughout the year with a new Swiss participant in the Steering Committee.

INDUSTRY AND MARKET DEVELOPMENT

For a few years, Swiss industrial PV products cover the full value chain starting from materials, production equipment and small scale manufacturing of solar cells, over diverse components and products all the way to system planning and implementation. Due to the fierce competition and the ongoing consolidation in the global PV industry, important changes have taken place in the Swiss PV industry landscape as well. Due to the decreased investment in new production facilities worldwide and slower market growth in Europe, the export volume of Swiss photovoltaic products has continued on a reduced level. At the same time, due to a comparatively strong domestic PV market, the export share is presently estimated at 50 % of the total turnover.

On the PV industry supply side, different products count among the world leaders. The largest equipment supplier for complete PV module manufacturing lines and advanced PV module technologies continues to be Meyer Burger. The company continues its efforts in advanced solar cell technology and has officially opened a silicon heterojunction solar cell pilot production line with CSEM in late 2014. The pilot line has a production capacity of 600 kilowatts from which heterojunction manufactured cells are built into modules and tested in both the laboratory and in the field. The target upon further process optimisation is to reach a PV module efficiency of 21 % with a production cost below 0,6 CHF/Wp. Measuring equipment for PV module manufacturers is produced by Pasan (a part of Meyer Burger Group). Solar plugging systems are offered by Multicontact as well as Huber & Suhner.

Flisom, a company active in the CIGS technology, has started setting up the facilities for a 15 MW pilot production in Switzerland. Flisom continues to work closely with the Swiss Federal Laboratories for Materials Testing and Research EMPA. Further companies are active in the manufacturing of coloured PV modules (swissinso) and dye-sensitized solar cells (glass to energy, Solaronix).

With the acquisition of the US company Power One, ABB has strengthened its business in the inverter market and is becoming a leading worldwide inverter supplier. One of the traditional Swiss PV inverter companies, Sputnik Engineering, had to close its business due to insolvency issues. On the other hand, Studer Innotec continues as a leading producer of stand-alone and grid-tied inverters, increasingly combined with storage units for self-consumption.

Alongside an increasing PV capacity being installed in Switzerland, a clear growth of the number of companies as well as that of existing businesses involved in planning and installing PV systems can be observed. Considerable know-how is available amongst engineering companies for the design, construction and operation of a large variety of different applications, ranging from small scale, stand-alone systems for non-domestic, professional applications and remote locations, over small domestic grid-connected systems to medium and large size grid-connected systems in various types of advanced building integration. System sizes have increased over the past years with up to 5 MW systems (Fig. 7) being installed on building complexes.

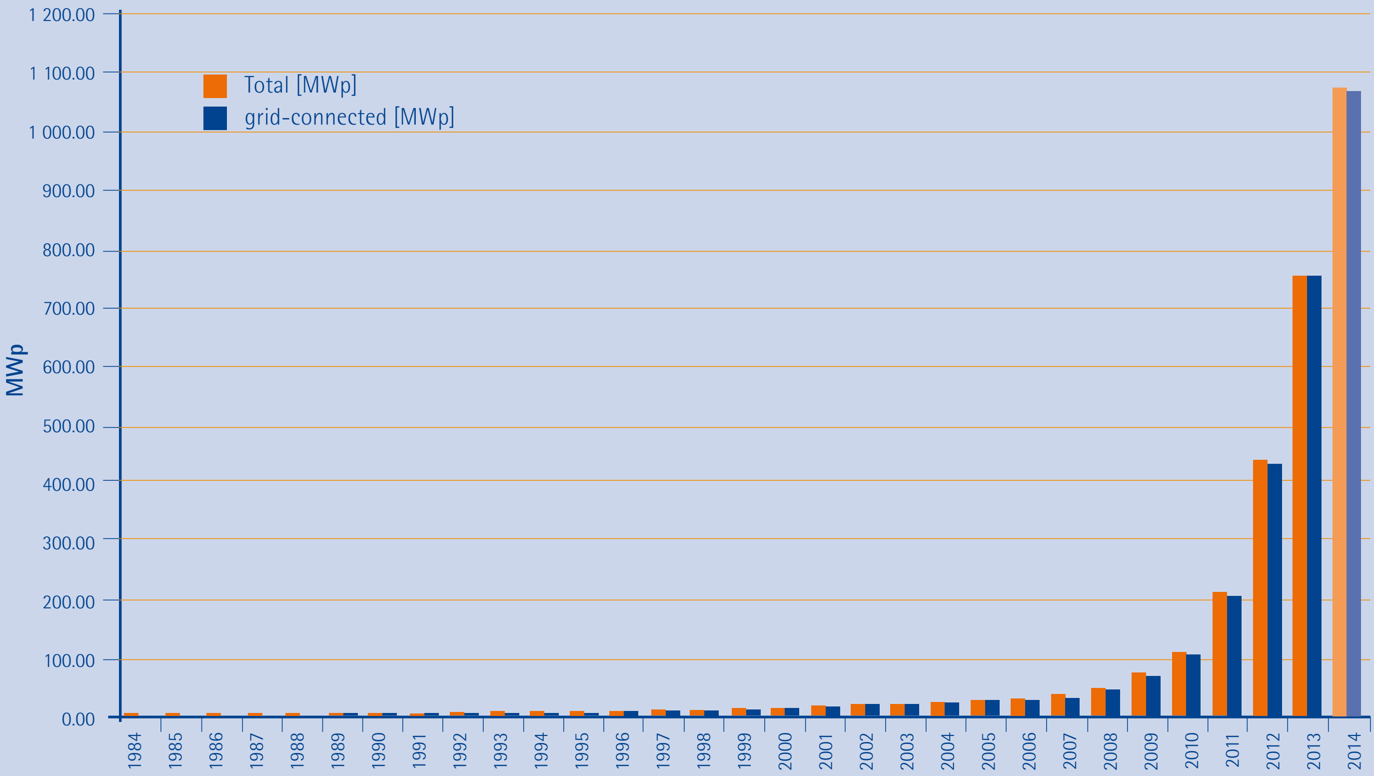

Fig. 8 – 30 years of PV in Switzerland: Evolution of the installed photovoltaic capacity in Switzerland between 1984 and 2014 (total and grid-connected, estimated values for 2014).

Formerly mostly driven by utilities own green power marketing schemes, there has been a strong development in the framework of the new feed-in tariff support scheme in recent years. This PV feed-in tariff distinguishes between three different categories of systems, namely ground based, building applied and building integrated systems (BIPV) for which the highest tariff can be obtained. The applicable tariff also depends on the size of the PV system. In this way, a differentiated scheme is used which is based on regular market analysis to follow the dynamics of the market. Due to the limited financial volume available within the feed-in tariff for PV systems up to now, many systems could not benefit from the feed-in tariff and are on a waiting list (see also introduction). This has led to a variety of intermediate support schemes by regional governments and utilities, thereby diversifying the possible market support.

The combination of the various support schemes and the increased cost-competitiveness of PV systems have led to an annual market volume for grid-connected systems estimated to at least 300 MWp, which represents about the same market size as for 2013. The total installed capacity has now risen to above 1 GW (Fig. 8) corresponding to about 130 W/capita. With this installed capacity, roughly 1 % of the annual national electricity consumption can now be covered by photovoltaics in Switzerland.