SWITZERLAND

PV TECHNOLOGY STATUS AND PROSPECTS
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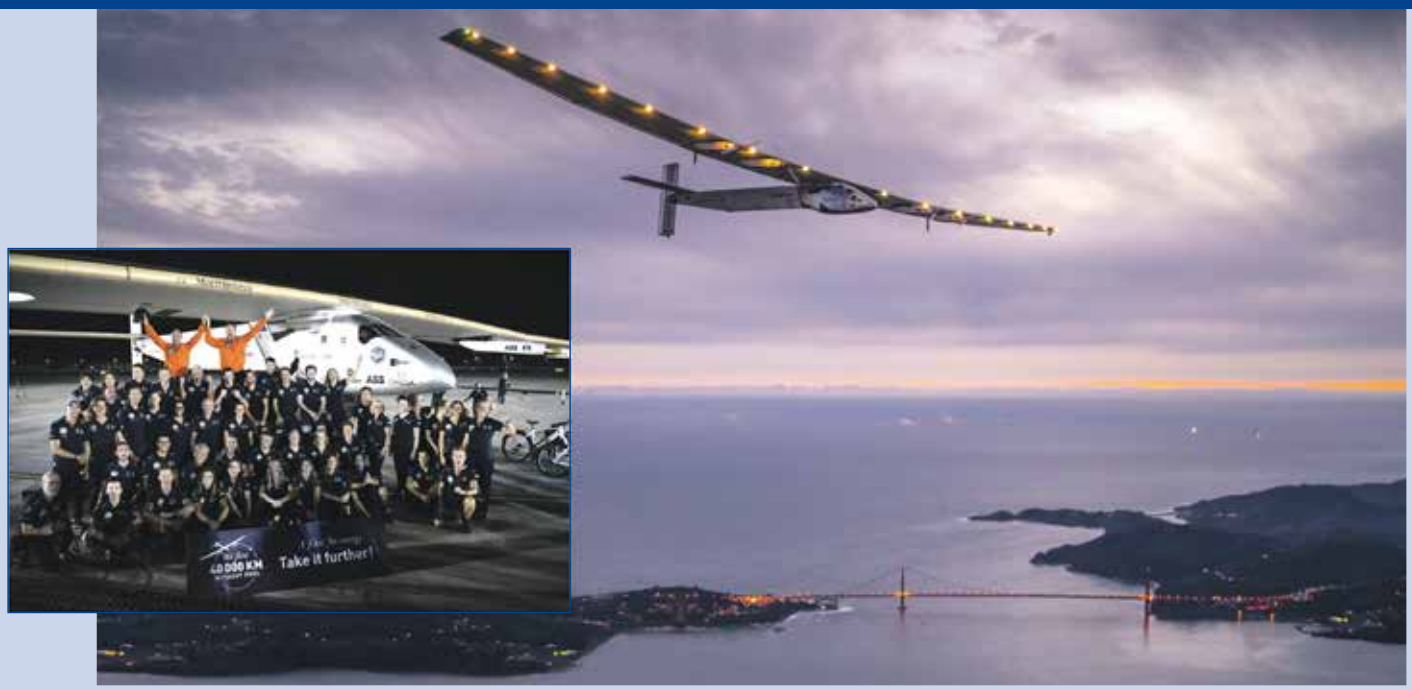

Fig. 1 - Solar Impulse 2 over San Francisco Bay area, 9th Leg. Hawaii to Mountain View Landing and SI2-Team after Landing and completion of the round the world flight in Abu Dhabi (Photos: ©Solar Impulse / Revillard / Rezo.ch / Chammartin).

GENERAL FRAMEWORK AND IMPLEMENTATION

Photovoltaic power systems continue to form a key pillar of the long term strategy for the future Swiss electricity supply. In all scenarios, the role of photovoltaics is acknowledged and expected to contribute in the order of at least 10 – 12 TWh to the national electricity supply by 2050 (60 TWh for 2016). The recent deployment trends (1,55 TWh end of 2016) are presently above the long term scenarios and underline that such contributions appear as feasible and possibly well before 2050.

In 2016, the first package of policy measures of the new energy strategy 2050 in conjunction with Switzerland's phase-out of nuclear energy were decided as an amendment to the energy law by the two political chambers (National Council and Council of States). These measures will have impacts on all levels from research to implementation and use, as well as regarding legislative and normative issues. A referendum has been taken against this political decision leading to a vote on the new energy strategy by Swiss citizens in May 2017.

Among the actions of the new energy strategy, an action plan for an increased energy research throughout all relevant energy technologies has been launched in 2013. Building on existing research activities, eight national competence centres for energy research (SCCERs) have taken up their research activities in seven different areas during 2014 and have accomplished their first term ending 2016. During 2016, the following term of the SCCERs for the period 2017 – 2020 was prepared and launched. The goal of these energy research centres is to build up new permanent research and innovation capacities, as well as institutional networks in the different technology areas, thereby accelerating the energy transition. In addition to the SCCERs, CSEM (Centre Suisse d'électronique et microtechnique) established a PV Technology Centre in Neuchâtel with the mission to support technology transfer and industrial development in the area of photovoltaics. Two complementary national research programmes – NRP 70 "energy turnaround" (www.nfp70.ch) and NRP 71 "Managing Energy Consumption" (www.nfp71.ch) – started their projects in 2015. Alongside these structural measures, important additional financial means have been foreseen to support research activities in the different areas on the project level. Moreover, the financial means for pilot and demonstration projects have continued on a high level, aiming at speeding up the technology transfer from research into industrial processes, products and applications.

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. A new edition has been approved in 2016 for the period 2017 – 2020. 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).

On the implementation level, three elements characterize the national regulatory framework for photovoltaic power systems: a onetime investment subsidy for systems up to 30 kW, a feed-in-tariff scheme for systems above 10 kW and, since 2014, measures for self-consumption. As the financial means for the different support schemes have their origin in a fixed levy on the electricity bill, there continues to be a cap on the total amounts available, resulting in a

particularly long waiting list for the feed-in-tariff for photovoltaic power systems. Therefore, self-consumption and new business models implemented by utilities and other commercial operators contribute increasingly to the market deployment.

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 (www.photovoltaic.ch). The SFOE research programme Photovoltaics 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. 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 standards and design tools.

The strategy to promote international co-operation on all levels continued, related to activities in the Horizon 2020 Programme of the European Union, the European PV Technology and Innovation Platform, the European SOLAR-ERA.NET Network, the IEA PVPS programme and in technology co-operation projects. SOLAR-ERA.NET (www.solar-era.net) is coordinated by Switzerland and continued in 2016 with a fourth joint call covering both PV and concentrated solar power (CSP). Furthermore, the new SOLAR-ERA.NET Cofund Programme started in late 2016 with another joint call. Within the IEA PVPS Programme, Switzerland presently leads Task 9 *Deploying PV Services for Regional Development* and the newly established Task 16 *Solar Resource for High Penetration and Large Scale Applications* (see this report p.15 to 20 and p.10).

RESEARCH, DEVELOPMENT AND DEMONSTRATION

In 2016, 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 research efforts. On the technical level, the topics of priority are silicon heterojunction cells, passivating contacts for high-efficiency crystalline silicon solar cells as well as different thin-film solar cell technologies for building integration. New concepts such as perovskite solar cells and tandem cells with these are increasingly being investigated. Further downstream, new approaches for building and grid integration are being developed and tested in pilot and demonstration projects.

Fig. 2 - Hofwiesen- / Rothstrasse, Zurich, detailed view of the façade. Modules from PVP Photovoltaik GmbH, glass-glass module, based on monocrystalline cells (Photo: ©Viridén + Partner AG, Zürich).

Work at the Swiss Federal Institute of Technology (EPFL) and the CSEM PV Technology Centre in Neuchâtel has focussed on heterojunction and passivating contacts for high-efficiency crystalline silicon solar cells. On the more fundamental R&D side, in a recent project on perovskite tandem structures, a perovskite silicon tandem solar cell of 21,2 % efficiency was presented in monolithic integration, and 25,2 % for 4 terminal measurements. Another highlight of the photovoltaic research at CSEM in Neuchâtel was achieved in collaboration with NREL in the United States: A dual junction gallium indium phosphide / crystalline silicon solar cell achieved a certified record efficiency of 29,8 %, with results over 30 % presented at the end of 2016. The Neuchâtel PV group extended its cooperation with PV and other industries.

With regard to CIGS solar cells, the Swiss Federal Laboratories for Materials Testing and Research EMPA have continued their work focussed on high efficiency flexible CIGS cells on plastic and metal foils. As for silicon solar cell research, the efforts are directed both to increased efficiency as well as industrial implementation. A more fundamental project explores the route towards 25 % efficiency CIGS solar cells. On the way towards industrial implementation of flexible CIGS solar cells, cooperation continued with the Flisom Company which is commissioning a new 15 MW pilot production plant.

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 21,6 %.

Organic solar cells are the research subject at EMPA, the University of Applied Sciences in Winterthur (ZHAW) as well as at CSEM in the Basel region.

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. Using new approaches and designs for surface appearance and coloured PV modules, a number of new pilot projects have made good progress in 2016 (Figures 2 & 3).

As a recent topic rapidly gaining relevance in some countries and regions, grid integration has continued to generate interest and innovative projects have extensively analysed the implications of

Fig. 3 - First energy self-sufficient apartment building in Switzerland is a project of the Umwelt Arena realised together with exhibition partners. The PV system on a multifamily building consists of an 80 kWp inroof system based on monocrystalline silicon roof system (512m² / MegaSlate II) and a 47 kWp micromorph silicon façade system (485 m²). (Photo: ©Umwelt Arena Schweiz, Architekt René Schmid Architekten, Zurich; "Umwelt Arena" is the world's first permanent exhibition dealing with the subject of environmental sustainability.).

PV on the distribution grid. Through detailed modelling work, methods to considerably increase the share of PV in distribution grids have been identified. 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 Southern Switzerland (SUPSI) and Bern (www.pvtest.ch) carefully evaluate products such as PV modules, inverters and new systems. A number of further Universities of Applied Sciences (e.g. ZHAW Winterthur, Wädenswil, Rapperswil) have strengthened their PV system infrastructure and analysis. Long term experience with the operation of photovoltaic power systems is carefully tracked for a number of grid-connected systems, ranging between 10 and more than 30 years of operation.

The solar powered airplane SolarImpulse (www.solarimpulse.com) by Bertrand Piccard, André Borschberg and their team successfully completed the first round the world flight in July 2016 in Abu Dhabi from where the flight started in March 2015 (Figure 1). In total, SolarImpulse covered over 40 000 km in 17 legs, flying from the United Arab Emirates to India, China, Japan and Hawaii in 2015, continuing in 2016 to the US mainland and finally the transatlantic flight to Spain, Egypt and completing the tour in Abu Dhabi.

The new SolarStratos project has been announced in 2016 by Raphaël Domjan, the founder of the solar boat PlanetSolar, aiming at a flight to the stratosphere at an altitude of 22 km with a solar powered airplane (www.solarstratos.com).

INDUSTRY AND MARKET DEVELOPMENT

Swiss industrial PV products cover the full PV value chain starting from materials, production equipment and small scale manufacturing of solar cells and modules, over diverse components and products all the way to system planning and implementation. After the consolidation period related to the global PV industry development of the past years, the signs confirm that the Swiss PV industry is overcoming this difficult period, based on new competitive technologies and products which very much relate to recent technology innovations.

The largest equipment supplier for complete PV module manufacturing lines and advanced PV module technologies continues to be Meyer Burger. The company increased its efforts in advanced solar cell technology (silicon heterojunction, smart wire, glassglass modules) and further developed a silicon heterojunction (HJT) solar cell pilot production line together with CSEM. The target of the pilot line upon further process optimisation was to reach a PV module efficiency of 21 % with a production cost below 0,6 CHF/Wp. The project has been successfully completed in 2016: Pilot lines were installed and ramped-up for HJT cells manufacturing, with innovations conducted at material, processes and design levels. The project enabled going from 21 % cell efficiency using lab-tools to 22,2 % average efficiency achieved with Meyer Burger mass-production equipment, and with efficiencies up to 22,8 % achieved with CSEM metallization R&D pilot line. The cumulated wafers, cells and modules costs using technologies demonstrated in this project result in a minimum calculated cost of 0,41 CHF/Wp (using standard wafer price) for the silicon heterojunction technology, achieving strong reduction in comparison to the initial project targets, and enabling for high competitivity. Other technology companies active in the supply of equipment for solar cell manufacturing include Indeotec and Evatec.

Flisom, a company active in CIGS thin film technology on flexible substrates, has progressed with the implementation of a 15 MW pilot production of flexible CIGS modules in Switzerland. The targets of the pilot line are certified 1 m wide flexible CIGS modules with 12 % efficiency. For this purpose, Flisom continues to work closely with the Swiss Federal Laboratories for Materials Testing and Research EMPA.

Small production facilities for PV modules are operated by Megasol, Meyer Burger and Sunage. Different companies are active in the manufacturing of coloured PV modules by various techniques, e.g. Swissinso (Figure 4 and cover picture), Solaxess and Üserhuus, as well as for dye-sensitized solar cells, e.g. glass-2-energy and Solaronix. Measuring equipment for PV module manufacturers is produced by Pasan (a part of Meyer Burger Group). Solar cabling and plugging systems are offered by Huber & Suhner, Leoni Studer and Multicontact. A number of companies work on mounting systems such as Designergy, dhp technology, Montavent or Schweizer Metallbau.

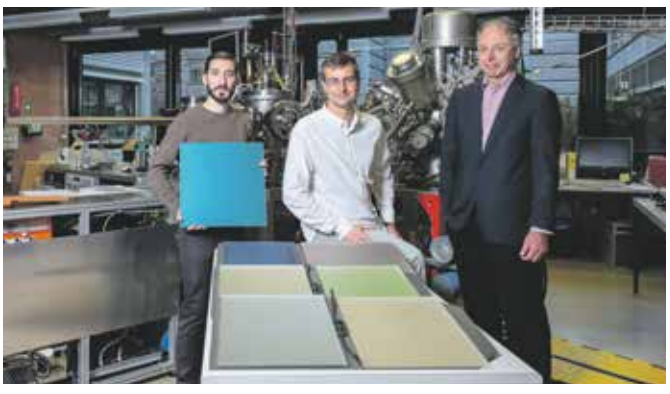

Fig. 4 - Research team working on development of laminated glazing with coloured reflection and high solar transmittance suitable for solar energy systems: Nicolas Jolissaint Engineer R&D of Swissinso, Andreas Schüler Research Associate, Jean-Louis Scartezzini Director of the Solar Energy and Building Physics Laboratory (Photo: ©EPFL, Alain Herzog).

Fig. 5 - Solar power plant Courgenay (JU). GEFCO, EDJ and BKW built Switzerland's presently most powerful solar plant. The installation comprises 23 886 modules built on a site measuring 43 000 m². It corresponds to the size of four and a half football pitches and also houses GEFCO Switzerland's car fleet. The new solar power plant has an installed capacity of 6,7 MWp, which covers an average consumption of over 1 550 households, and is therefore Switzerland's most powerful photovoltaic installation (Photo: ©BKW).

Based on the US company Power One, ABB is now a leading worldwide inverter supplier. ABB is further active in the technologies for PV grid integration. 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 6,7 MW systems being installed on building complexes. In recent years, the support schemes have evolved and, depending on size and type of the PV system, different support conditions apply. Moreover, in order to compensate for the long waiting list for the feed-in-tariff, intermediate support schemes by regional governments and utilities have diversified the possible market support. As a consequence of the capped support within the feed-in-tariff scheme and the resulting waiting list, the annual market volume for grid-connected systems is estimated at 250 MWp for 2016, about 25 % lower than 2015. The total installed capacity by the end of 2016 has risen to above 1,6 GW (Figure 6) corresponding to about 200 W/capita. With this installed capacity, close to 2,5 % of the annual national electricity consumption can now be covered by photovoltaics in Switzerland, which ranks PV number two in renewable electricity sources in Switzerland after hydro power.

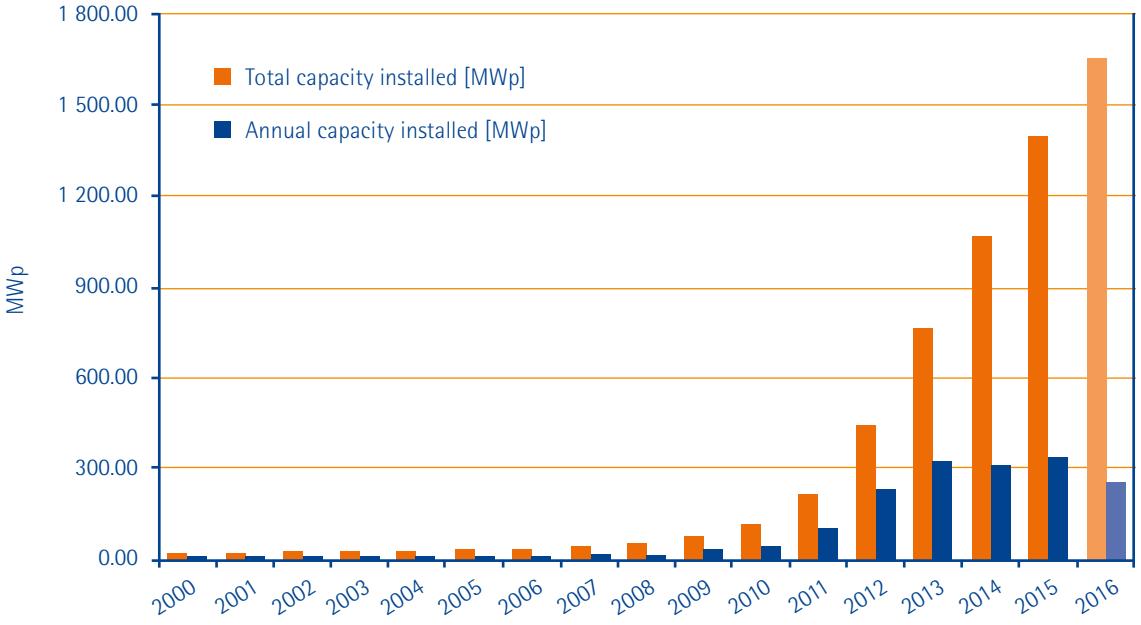

Fig. 6 – Evolution of the installed photovoltaic capacity in Switzerland since the year 2000 (total and annual installed capacity, estimated values for 2016).