

SWITZERLAND

PV TECHNOLOGY STATUS AND PROSPECTS

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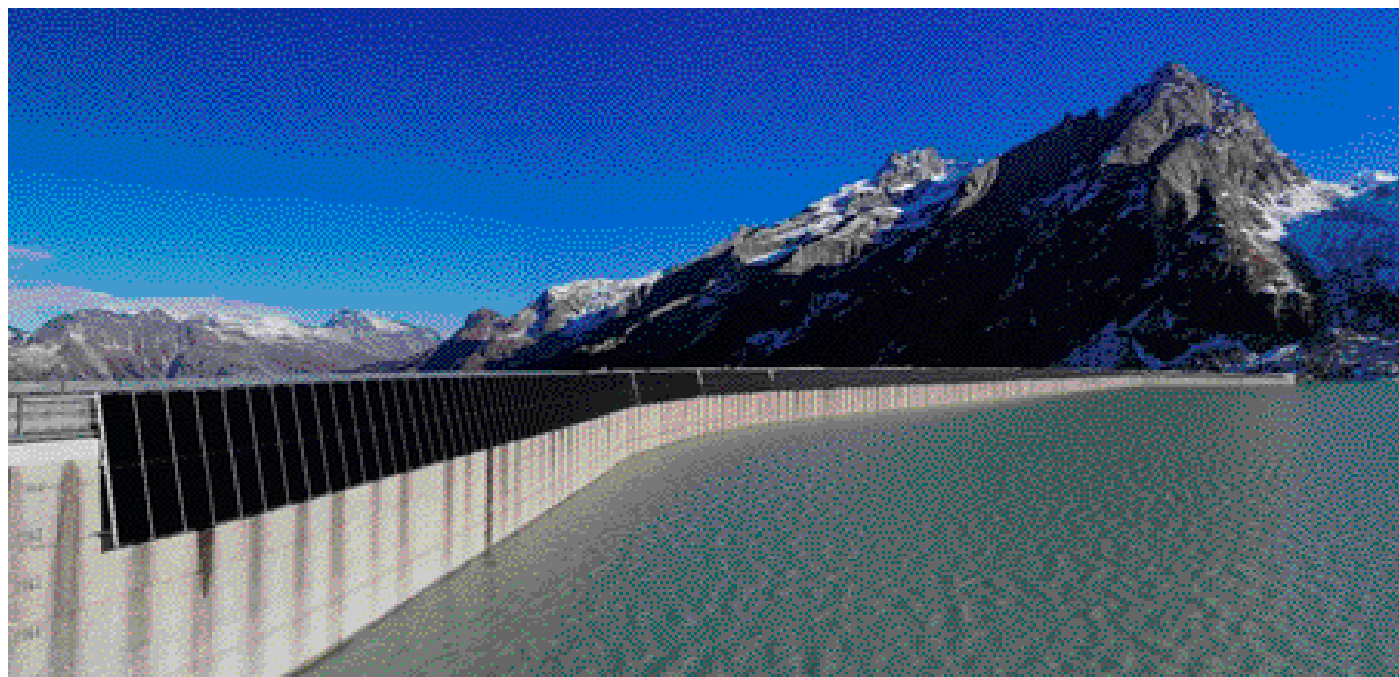


Fig. 1 - In September 2020, a high-alpine 410 kWp PV system was commissioned by the Zurich power utility ewz at the Albigna Dam at 2,165 m. Due to its location the installation is subjected to extreme meteorological conditions. The analysis of the yield data, periodic measurement of the module output, thermal imaging and examination of the general condition of the system will be used to gain insights on the long-term reliability of installations installed at comparable locations (Photo: © Reech GmbH).

GENERAL FRAMEWORK AND IMPLEMENTATION

With the “Energy Strategy 2050” Switzerland has embarked on a path to make its energy system more sustainable and climate-friendly, while at the same time ensuring a high level of security of supply. Since around three quarters of greenhouse gas emissions in Switzerland are caused by the use of fossil fuels, the energy strategy is closely related to climate policy. Here, the focus lies on a total revision of the CO₂ Act, which in 2020 has been adopted by parliament after almost three years of consultation and on which a popular referendum will be held in 2021, with possible entry into force January 2022.

With the revised CO₂ Act as the national implementation of the Paris Climate Agreement, Switzerland aims to halve its greenhouse gas emissions by 2030 compared to 1990 levels. Switzerland's final goal by 2050 is to emit not more greenhouse gases than natural and artificial reservoirs can absorb (net zero emission target). With a reduction of only 15%, the current target of reducing greenhouse gas emissions by 20% by 2020 compared to the 1990 level was missed. With the revised CO₂

Act, various measures are foreseen: in transport, the emission regulations for new cars (including heavy-duty vehicles) will be further tightened; the producers and importers of fossil fuels will have to compensate for a greater proportion of CO₂ emissions; for buildings, the CO₂ tax on fossil fuels is to be continued and if necessary increased to accelerate the switch to renewable forms of heating; in the industrial sector, flexible measures should further reduce emissions; and finally, Switzerland's emissions trading system has been linked to that of the EU.

In November 2020, first results of the updated Swiss Energy Perspectives for 2050 (EP 2050+) have been published. The EP 2050+ analyse a development of the energy system that is compatible with the long-term climate goal of net zero greenhouse gas emissions in 2050 (“net zero”) and at the same time ensures a secure energy supply. According to EP 2050+, in 2050, domestic power production will be almost exclusively by hydropower plants and renewable energies including combined heat and power plants (CHP plants). New renewable energies shall supply

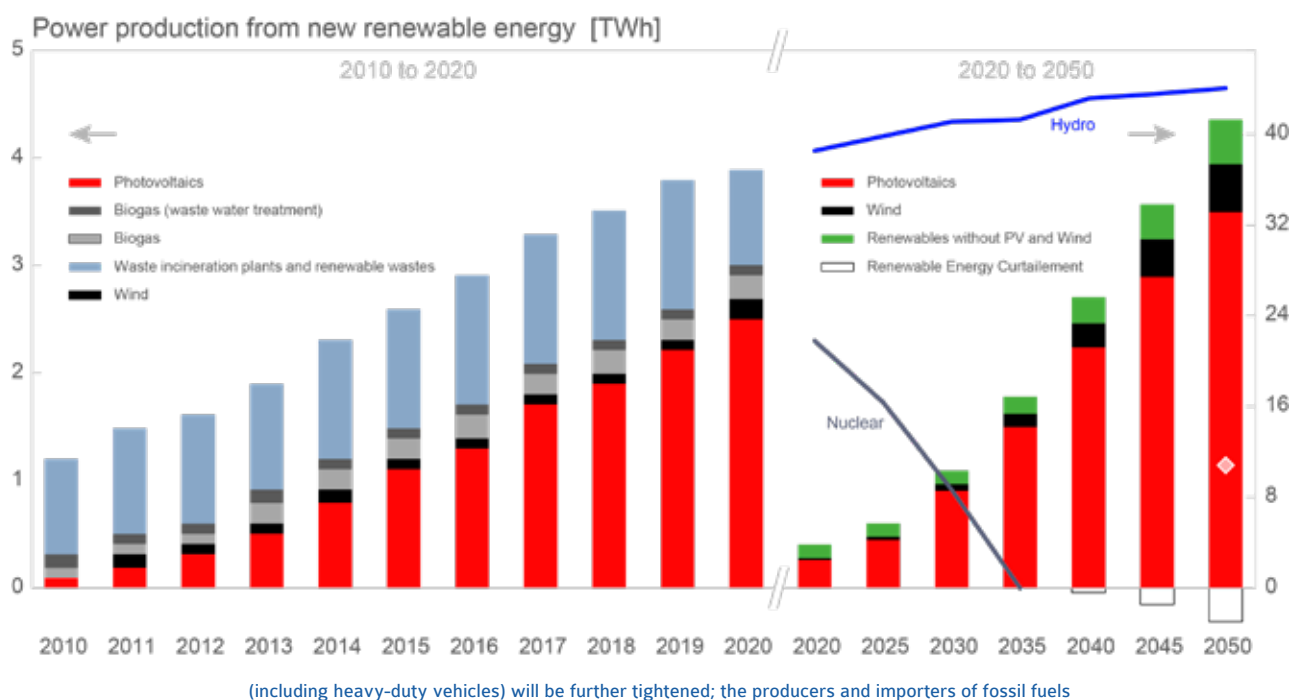


Fig. 2 - Development of power production from new renewable energies 2010 to 2020. Switzerland's most important domestic energy source is hydropower and its exploitation in run-of-river and storage power plants covers around 56% of Switzerland's electricity needs. Today, hydropower accounts for almost the entire share of renewable electricity production, at around 96%. The 2020 target value for supplementary generation from other /new renewable energies such as PV, Wind and others is 4 TWh, what was achieved thanks to continuous increase of PV capacity. The right part shows power production from new renewables in a "net zero" scenario, which is nearly entirely based on a strong increase of PV power production with a smaller contribution from wind energy. The target value for PV in 2050 has tripled (from 11.4 to 34 TWh) compared to the previous perspectives (the diamond in the column 2050 denotes the previous PV target value of 11.4 TWh). Nuclear power production fades out, while production from hydropower will increase only slightly. Electricity consumption (not shown) will also increase due to electrification in mobility (Data Source: <https://www.bfe.admin.ch/bfe/de/home/politik/energieperspektiven-2050-plus.html>).

39 TWh or 46% of gross electricity generation with 34 TWh from photovoltaics (40% of generation, today around 3%, 2 TWh) [1]. Electricity imports in winter are increasing on a short term and will decrease again approaching 2050, since with increasing PV capacity also the winter share of electricity generation by PV rise to over 30% in 2050. In addition, hydro storage plants can shift their flexible production into the winter depending on demand.

Today, the PV market in Switzerland is driven by self-consumption with an expansion rate of around 0.3 GW/year. In order to achieve the goals formulated in the Energy Perspectives, new market stimuli are needed for new large photovoltaic installations without self-consumption (e.g. on agricultural, commercial and office buildings). Proposals for tenders are discussed as part of the revision of the Energy Act. In the medium term, a rate of capacity expansion in the order of 1 GW/year is required.

NATIONAL PROGRAMME

The Swiss Federal Office of Energy (SFOE) runs a photovoltaic RTD programme that involves a broad range of stakeholders. The programme is part of the long-standing coordinative activities by the SFOE to support research and development of energy technologies in Switzerland, where funds deployed in a subsidiary manner aim to fill gaps in Switzerland's funding landscape. Grants are given to private entities, the domain of the Swiss Federal Institutes of Technology (ETH), universities of applied sciences and universities.

The focus of the photovoltaics programme lies on RD&D from basic research, over applied research, product development, pilot and demonstration projects. On average, the volume of the SFOE programme support (including pilot and demonstration) is in the order of 10% of the total public support for photovoltaics research in Switzerland, which is in the order of 36 MCHF per year (including roughly 30% from European projects) (<https://pv.energyresearch.ch/projects>).

[1] The Swiss PV potential on buildings, analysed from data of a national solar potential cadastre (www.sonnendach.ch) and meteo data, is on the order of 67 TWh. Of these, 50 TWh are from rooftops in combination with an additional potential of 17 TWh from façades. In this potential analysis, only larger surface areas with economically useful insulation are considered.



Fig. 3 - Swiss photovoltaics technology landscape (without claim of completeness). Circles denote academic institutions, squares industrial actors (source <https://pv.energyresearch.ch/actors>). Actors are classified according to: (1) "Solar cells": Research and development of various solar cell technologies, material supply, process equipment, recycling. (2) "Modules BIPV": Modules and BIPV, activities around the topic of PV modules (materials, process equipment, testing and quality assurance). (3) "System technology": System aspects of photovoltaics, inverters, electrical components, quality assurance, grid integration, storage. (4) "Other (LCA, solar resources)": Life cycle analysis, solar resource analysis and forecasting.

The SFOE photovoltaics programme supports research and pilot & demonstration in different areas of photovoltaic cell technologies (namely c-Si, CIGS and perovskites), in the field of photovoltaic modules and building integration of photovoltaics, as well as in the topics of system aspects of photovoltaics such as grid integration, quality assurance of modules and inverters or battery storage technology. Other topics are life cycle analysis, solar forecasting and performance monitoring. International co-operation on all levels, 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 Technology Collaboration Programme and in technology co-operation projects is another key element of the programme.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

Swiss actors in academia and in industry are dealing with all kind of different aspects of photovoltaics (see Figure 3). In the field of solar cells the focus lies on high-efficiency crystalline silicon solar

cells (heterojunction technology, PERC, passivating contacts) and in CIGS cells. Perovskite solar cells and tandem cells (c-Si with perovskite or III/V, CIGS with perovskite) are other topics of high interest.

The development of new module architectures, especially for building integration applications, is another large field of research with new approaches and solutions for coloured, light-weight and flexible modules as well as customized modules. Grid integration of photovoltaics, photovoltaics in combination with heat pumps and storage technologies (batteries, thermal storage), photovoltaics and electro-mobility (bidirectional charging) are other themes with ongoing and increased activities. System performance of photovoltaics is a topic at various universities and research centers, some of them such as the Bern University of Applied Sciences (BFH) and the University of Applied Sciences of Southern Switzerland (SUPSI), with the monitoring of photovoltaic installations for many decades.



R&D HIGHLIGHT 2020:

New forecast method on imperfect PV production measurements

A critical element for enabling large-scale penetration of PV generation into the power grid lies in the precise forecasting of production. Power production by PV is characterized by significant variability since it depends on meteorological conditions. In an R&D project by the Centre Suisse d'Electronique et de Microtechnique (CSEM) and the Swiss utility BKW Energie completed in 2020, a new method for multi-site PV forecasting was developed, starting from the premise that PV systems by themselves provide a dense network of simple weather stations, since PV production data can indirectly provide meteo data.

Based on the outcomes of a first proof-of-concept, the applicability of big-data analytics to forecast of power generation of distributed PV systems all over Switzerland was demonstrated. The developed algorithms have been tested with more than 300 real PV systems spread over Switzerland, and 1 000 synthetic ones that reproduce the statistical distribution of installed PV in the country in terms of size, orientation and location. The new methods outperform state-of-the-art techniques which combine numerical weather

Degradation of perovskite solar cells under reverse bias

Partial shading caused by vegetation, building structures, soiling or snow drives the shaded cells in a module into reverse bias as they are required to pass the reverse current of illuminated neighbors. The time spent in reverse bias can have a permanent detrimental impact on the integrity of the cells in a module. That is why there are IEC (International Electrotechnical Commission) protocols to test the partial shading resilience of PV modules that any commercially relevant perovskite technology would have to demonstrate. Researchers in Neuchâtel (at EPFL Neuchâtel and the CSEM PV-Center) combine optical, microstructural, and electrical characterization to understand the degradation mechanisms in perovskite solar cell degradation under reverse bias.

Only one of three identified mechanisms on how perovskite solar cells are degrading is reversible to some extent, while the other two are irreversible with the formation of shunts. The results out of this project underline the urgent need to develop cell designs that are far more robust to partial shading conditions compared to current state-of-the-art perovskite solar cell devices.

(<https://doi.org/10.1039/C9TA12032G>)

Weather balloons with flying photovoltaic technology from CSEM

Over the past years, the Centre Suisse d'Electronique et de Microtechnique CSEM has developed ultra-light customised photovoltaic modules. These are now being used in a French research project (STRATEOLE-2) to ensure the energy supply of weather balloons. The project will use balloons to study interactions between the troposphere and stratosphere in the equatorial belt over the Indian Ocean. The specifications for the PV modules are very demanding: maximum weight of about one kilo per square metre, i.e. about ten times less than a standard

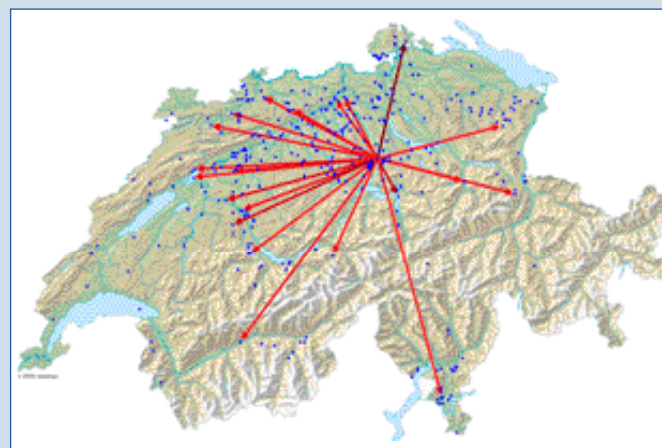


Fig. 4 - PV forecast methods based on the assumption that the current power production can be modelled as a function of the past production data of a subset of nodes over a predefined time interval. The rationale behind is that events in the past production (e.g. clouds) are informative to predict the production in other nodes. Graph-based methods were used to reconstruct missing or faulty data. The figure on the left shows an example of a set of PV production site for the forecasting a node in central Switzerland (Graphics: CSEM).

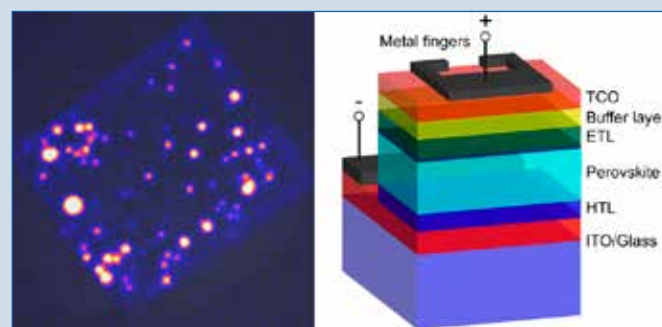


Fig. 5 - (Left) Lock-in thermography image of a semi-transparent perovskite solar cell exposed to a reverse bias of -3V showing hot-spot/shunt formation over the entire cell area. (Right) Schematic of a semi-transparent perovskite solar cell architecture, such as it would be used in a tandem cell configuration (with the Si bottom cell replacing ITO/Glass) (Source: EPFL/CSEM).



module, extreme conditions with low temperatures, huge thermal cycles and high UV radiation in the stratosphere. These modules are especially interesting for PV mobility applications (source: <https://www.csem.ch/page.aspx?pid=159509>).



Fig. 6 - Leverage for cost reduction lies in increasing efficiency of modules, the reduction of material costs and high module reliability. An industrial R&D project within the framework of a European cooperation ([SOLAR-ERA.net](https://solar-era.net)) has made significant contributions to these challenges by combining fine-line metallization of solar cells with the cell connection technology from Meyer Burger. On the cell level, silver paste consumption for metallization could be lowered to 5 mg/Watt, which is far ahead in the photovoltaic technology roadmap. With the modules built and tested with this approach, the total module power exceeded by 15 watts compared to commercial 3 busbar modules (Photo: Meyer Burger).

NEWS FROM INDUSTRY

Swiss industrial players are grouped along the entire photovoltaics 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, including recycling (see Figure 3). A broad range of competitive technologies, products and services are offered to the growing photovoltaic market, both domestically and abroad.

2020 was a year of transformation for the Swiss company Meyer Burger with a complete reorientation from a supplier of equipment to a manufacturer of solar cells and modules based on its own heterojunction/smart-wire technology, developed in Switzerland over the past 13 years in strong collaboration with Swiss research institutions. In order to be able to finance the transformation, the company successfully completed a capital increase of 165 MCHF, following the approval of the shareholders at the extraordinary general meeting in July 2020. Meyer Burger selected the traditional solar locations in Germany (Bitterfeld-Wolfen in Saxony-Anhalt and Freiberg in Saxony) to set up production facilities. Production start is planned for the first half of 2021, with 400 MW solar cells and 400 MW solar module. Expansion of the production up to 5 GW is planned.