IEA INTERNATIONAL ENERGY AGENCY

National Survey Report of Photovoltaic Applications in Switzerland 2017

Terracotta-red solar panels installed on the roof of a protected farmhouse in Ecuvillens
Foto: © CSEM/Issol, Neuchâtel

PVPS

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

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On behalf of the Swiss Federal Office of Energy

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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 member countries

The IEA Photovoltaic Power Systems Technology Collaboration 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 participating countries and organisations can be found on the www.iea-pvps.org website.

The overall programme is headed by an Executive Committee composed of one representative from each participating country or organization, 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

Introduction

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems. Task 1 activities support the broader PVPS objectives: to contribute to cost reduction of PV power applications, to increase awareness of the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers and to enhance technology co-operation. An important deliverable of Task 1 is the annual "*Trends in photovoltaic applications*" report. In parallel, National Survey Reports are produced annually by each Task 1 participant. This document is the country National Survey Report for the year 2017. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

The PVPS website www.iea-pvps.org also plays an important role in disseminating information arising from the programme, including national information.

1 INSTALLATION DATA

The PV power systems 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. Other applications such as small mobile devices are not considered in this report.

For the purposes of this report, **PV installations are included in the 2017 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2017, although commissioning may have taken place at a later date**.

1.1 Applications for Photovoltaics

In 2017, the Swiss market decreased by 10% to 242 MW, corresponding to 28 W/capita. After 2016, this is the second year that the newly installed PV capacity is declining in Switzerland. Limitations and uncertainties of new funding for the supporting scheme as well as reduced buy-back tariffs payed by the Distribution System Operators had a negative impact on the development of PV.

This can be seen particularly in the segment of large installations (> 100 kW), where the installed capacity decreased by 34%. Since small installations below 30 kW DC still had a guaranteed right for direct subsidies (one-time remuneration), an increase in both numbers (+46%) and installed capacity (+38%) of smaller installations (mostly on Single Family Homes) can be observed. A high self-consumption rate remains the key for profitable operation of PV systems, not only for residential but also for commercial and industrial systems.

While there is little to no market for ground-mounted or agricultural PV (due to constraints on available land), an increasing number of building integrated and PV projects on façades can be observed. This development is driven by technological advancements (colour & shape of modules) as well as by increasing awareness of architects to use PV as a building element (see for example the picture on the front page). Likewise, several large PV installations on carports have been realised.

Every year the Swiss Solar Prize (https://www.solaragentur.ch/node/775) is awarded to innovative or highly remarkable PV projects. Two examples for 2017 are given below:

Figure 1: 440 kW PV installation at Grosspeter Tower, Basel (left) and 1.4 MW on a Football Stadium in Schaffhouse (right). © Solaragentur

In **May 2017**, the Swiss population accepted the new energy act (as part of the Energy Strategy 2050) with the objectives to:

- increase energy efficiency in buildings, mobility, industry and appliances
- increase the use of renewable energy by improving the legal framework and by promotion
- put a ban on new generation licences for nuclear power plants

The declared target for domestic production of renewable energy (excluding hydropower) is 11'400 GWh by 2035, corresponding to approximately 20% of the domestic electricity consumption.

Thanks to an increase of the network surcharge from 1.5 ct/kWh to 2.3 ct/kWh from 2018 onwards (which applies, with some exceptions, to all electricity consumers), new funding for the promotion of renewable energies will be available and will allow to reduce the current list of more than 35'000 PV projects waiting for a positive decision for feed-in subsidies. Positive in this regard is the fact that the one-time remuneration (covering up to 25-30% of the initial investment) is no longer limited to installations smaller 30 kW but can be obtained for systems up to 50 MW.

On the negative side of the new energy act, from a PV point of view, are a 20% reduction in feed-in tariffs together with a reduction of the duration the feed-in tariff is obtained from 20 to 15 years, as well as the limitation of the promotion by 2023 (no new commitments in the feed-in premium scheme) and 2031 (no new one-time remuneration).

Other important changes are:

- Changeover from current feed-in remuneration at cost scheme to feed-in remuneration with direct marketing for installations. The threshold is > 500 kW for installations that are already benefitting from a feed-in remuneration and > 100 kW for installations newly entering into the feed-in remuneration scheme.
- Facilitated collective self-consumption
- Basis for introduction of Smart Metering

1.2 Total photovoltaic power installed

On behalf of the Swiss Federal Office of Energy, Swissolar is mandated to survey the Swiss solar market and publish the annual installed capacity in the Report: "Markterhebung Sonnenenergie 2017". The data therein is based on a survey amongst 616 companies active in the PV and solar thermal market. About 90% of installers, importers/distributers and manufacturers are estimated to be covered in this annual market survey.

The installed capacity of 1,91 GW by the end of 2017 has produced approximately 1'683 GWh, corresponding to 2.9% of Switzerland's electricity demand in 2017.

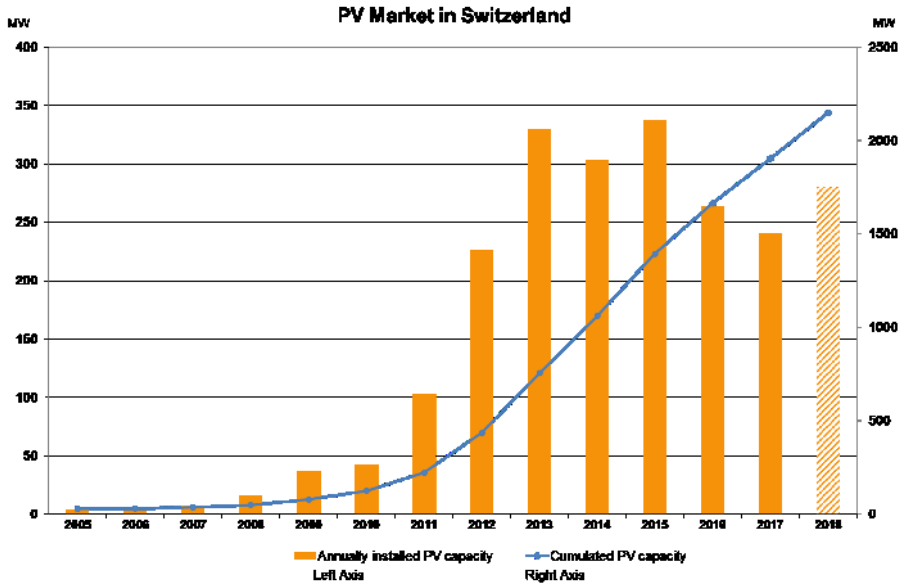

Table 1a: PV power installed during calendar year 2017

AC			**MW installed in 2017**	**MW installed in 2017**	**AC or DC**
Grid-connected	BAPV	Residential < 30 kWp	208 MW	100 MW	DC
		Commercial 30-100 kWp		23 MW	DC
		Industrial > 100 kW		85 MW	DC
	BIPV	Residential < 30 kWp	32 MW	15 MW	DC
		Commercial 30-100 kWp		4 MW	DC
		Industrial > 100 kW		13 MW	DC
	Utility-scale	Ground-mounted	1 MW	1 MW	DC
		Floating		-	
		Agricultural		-	
Off-grid		Residential (SHS)	390 kW		DC
		Other			DC
		Hybrid systems			DC
		Total	242 MW		DC

Table 2b: Segmented grid-connected PV power installed during calendar year 2017 as a function of system size

System size (kW)	Capacity installed in 2017 (kW)	Numbers of systems in 2017
< 4 kW	3'179	1'228
4- 20 kW	78'945	8'837
20- 30 kW	35'051	1'489
30-50 kW	9'092	239
50-100 kW	16'522	228
100 -1'000 kW	88'560	358
> 1'000 kW	9'086	7
Unknown	1'565	609
Total	**242'000**	**Approx. 13'000**

Table 2: Data collection process:

PV data collection	Data are collected in DC
Is the collection process done by an official body or a private company/Association?	The data collection process is done by Swissolar (Swiss Solar Professional Association) on behalf of the Swiss government. It is based on a questionnaire sent to all importers, installers and manufacturers. It is estimated, that about 90% of the market is covered with this survey. To validate the data, there is a compulsory registration for systems above 30 kVA since the beginning of 2013 (Guarantees of origin and electricity labelling). The Swiss Federal Office of Energy has been surveying the solar market in Switzerland for more than 20 years. Due to this long experience the quality of the data has been maintained, thanks as well to all the installers and distributers who are willing to complete the annual questionnaire. The report has been published by the Swiss Federal Office of Energy in July 2018 and also serves as a basis for the annual renewable energy statistics.
Link to official statistics	Solar Energy market survey 2017 (DE/FR): https://www.swissolar.ch/fr/lenergie-solaire/faits-et-chiffres/enquetes-de-marche/ Electricity Statistics 2017 (DE/FR): http://www.bfe.admin.ch/themen/00526/00541/00542/00630/index.html?lang=en&dossier_id=00765 Overall Energy Statistics 2017 (DE/FR): http://www.bfe.admin.ch/themen/00526/00541/00542/00631/index.html?lang=en&dossier_id=00763
Additional comments	The quality and accuracy of the data is expected to be better than +/- 10%.

Table 3: PV power and the broader national energy market.

	2017 numbers	2016 numbers
Total power generation capacities (all technologies)	**21.4 GW total** (3.33 GW nuclear, 15.4 GW hydro, 2.75 GW new RE & thermal)	**20.8 GW total** (3.33 GW nuclear, 14.8 GW hydro, 2.7 GW new RE & thermal)-
Total power generation capacities (renewables including hydropower)	**17.6 GW total** (15.4 GW hydro, 1.91 GW PV, 75 MW wind, 211 MW waste)	**16.7 GW total** (14.8 GW hydro, 1.66 GW PV, 75 MW wind, 211 MW waste)-
Total electricity demand (= consumption)	58.5 TWh (+ 0.4%)	58.2 TWh
Total energy demand (= final consumption)	849 790 TJ (-0.4%)	852 900 TJ
New power generation capacities installed during the year (all technologies)	+ 242 MW PV + 545 MW hydro	+ 271 MW PV + 989 MW hydro
New power generation capacities installed during the year (renewables including hydropower)	+ 242 MW PV + 545 MW hydro	+ 271 MW PV + 989 MW hydro
Total PV electricity production in GWh-TWh	1'683 GWh	1'333 GWh
Total PV electricity production as a % of total electricity consumption	2.9%	2.3%

Table 4a: Other information

	2017 Numbers
Number of PV systems in operation in your country	Approx. 71'400*
Capacity of decommissioned PV systems during the year in MW	< 0.5 MWp (estimates)
Total capacity connected to the low voltage distribution grid in MW	Approx. 95% Normally up to 1 MVA can be connected to the low voltage grid
Total capacity connected to the medium voltage distribution grid in MW	Approx. 5%
Total capacity connected to the high voltage transmission grid in MW	0%

* Based on the market survey "Markterhebung Sonnenenergie 2017", July 2018, Swiss Federal Office of Energy

Table 4b: Grid-connected PV Systems – Market Segmentation (numbers)*

	2017 Newly added	***2016 Newly added***	**2017 Cumulated**
Single Family Homes	9'131	*6'317*	43'431
Apartment Buildings	1'299	*834*	6'299
Industrial Buildings	864	*721*	8'764
Farm Houses	503	*608*	7'603
Commercial Buildings	133	*110*	1'033
Municipal & State-owned Buildings	311	*244*	3'151
Traffic Infrastructure and Buildings	6	*13*	106
Others	140	*453*	1'000
Total	**12'387**	***9'300***	**71'387**

* Based on the market survey "Markterhebung Sonnenenergie 2017", July 2018, Swiss Federal Office of Energy and earlier year's statistics

In 2017, the number of installations increased by 33% compared to 2016. The largest segment (almost ¾) are single family homes with a 45% increase compared to 2016. Since at the same time the total installed capacity has decreased by 10%, this matches the tendency to

- fewer large scale installations
- a slight decrease in average size for single family homes from 9 to 8 kW

The shift to smaller installations can be explained by the fact that under the current legislation (reducing buy-pack tariffs of DSO and limited funding for Feed-in tariffs) a high degree of self-consumption is required in order to be profitable (hence the tendency to reduce the size of the PV system).

The obligation to include a minimum amount of PV (10 W/m^2 of heated area) in new buildings is also partly responsible for a growing number of PV installations on residential buildings.

Table 5: The cumulative installed PV power in 2 sub-markets (MWp).

Year	Off-grid (including large hybrids)	Grid-connected distributed (BAPV, BIPV)	Total
1992	1.6	3.1	4.7
…	…	…	…
2000	2.6	12.7	15.3
…	…	…	…
2005	3.3	23.8	27.1
…	…	…	…
2010	4	107	111
2011	4	207	211
2012	4	433	437
2013	4	752	756
2014	4	1’057	1’061
2015	4	1’390	1’394
2016	4	1’660	1’664
2017	4	1’902	1’906

Swiss PV market (in terms of newly installed capacity) decreased by 10% in 2017 to 242 MW, corresponding to 28 W/capita. Uncertainties regarding new funding and a market shift to smaller installations are seen as the main reason. With the new legislation having come into force on January, new but still limited funding will be available. Together with improved conditions for collective self-consumption, the market outlook for 2018 looks again more promising.

1.3 Key enablers of PV development

Table 6: information on key enablers

	Added volume in 2017	Additional information	Source
Decentralized storage systems	**Storage capacity:** 10’325 kWh (95% Li-ion, 5% lead-acid battery) **Number of systems:** 1’260 (97% Li-ion, 3% lead-acid battery)	Compared to 2016, annual number and capacity of decentralized Li-ion storage systems has increased by a factor of 3	https://www.swissolar.ch
Residential Heat Pumps	20’000 (+8% compared to 2016)	More than half of all installed heat pumps fall in the range of 5-13 kW. 70% of all heat pumps are air/water. Today approx. 1/5 of all buildings are heated by a heat pump	http://www.fws.ch
Electric cars (and light weight)	16’803 (+ 19% compared to 2016)	This corresponds to 5.35 % of newly registered cars (4'773 EV and 12'030 Hybrids)	https://www.swiss-emobility.ch

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

Table 7: Typical module prices for a number of years (average prices in CHF, excluding VAT)

Year	2005	2010	2011	2012	2013	2014	2015*	2016*	2017*
Standard module crystalline silicon price for small systems in the range of 3 to 10 kWp	4.80	3.60	2.50	1.30	1.00	0.95	0.90	0.80	0.75
Average price, large systems (> 100 kWp)	4.60	2.20	1.30	0.85	0.80	0.57	0.55	0.50	0.45

*the strong Swiss Franc continues to have a positive effect on module cost

2.2 System prices

A summary of typical system prices is provided in the following tables (excluding VAT)

Table 8: **Turnkey Prices of Typical Applications – local currency (CHF)**

Category/Size	Typical applications and brief details	Current prices per W
OFF-GRID Up to 1 kW (SHS)	Holiday houses, with battery and approx. 3d autonomy, only DC consumers (no inverters) Cost is mostly driven by battery and not PV size	10 to 15
OFF-GRID > 1kW scale	Mostly alpine huts (chalets) in the range of maximum up to 10-20 kW, including inverters and batteries for approx. 3d autonomy Cost is mostly driven by battery and not PV size	8 to 17
Grid-connected Rooftop up to 5-10 kW (residential BAPV)	Residential houses, BAPV	2.2 to 4.0
Grid-connected Rooftop from 10 to 250 kW (commercial BAPV)	BAPV	1.1 to 2.5
Grid-connected Rooftop above 250kW (industrial BAPV)	BAPV	0.9 to 1.5
Grid-connected Ground-mounted above 10 MW	No market in Switzerland	N/A
Floating PV	Only demonstrator plants	N/A
Agricultural PV	No market in Switzerland	N/A
Residential BIPV (tiles, or complete roof, 5-10 kW).	+15% for new buildings, otherwise + 25% compared to BAPV	2.5 to 5.0
Commercial BIPV (10-250 kW)	+15% for new buildings, otherwise + 25% compared to BAPV	1.5 to 3.0

Table 9: National trends in system prices (current) for different applications – local currency (CHF)

Price/Wp	1995	2000	2005	2010	2015	2016	2017
Small residential PV systems 3-4 kW	12.8	12.5	10.0	7.0	3.0 - 5.0	3.0 – 5.0	2.8 – 4.5
Large residential PV systems 10-20 kW	11.8	9.9	8.5	6.5	2.2 - 3.5	2.2 – 3.5	2.1 – 3.3

There is an increased tendency for residential PV systems to install additional "gadgets" such as an additional meter to monitor self-consumption or to regulate the heat pump or the electric water heater based on the PV production.

2.3 Cost breakdown of PV installations

No comprehensive cost survey has been published for 2017. The indicative cost breakdown in the following tables is based on data for several offers for small and large systems received in 2017. Especially for residential systems there is a significant variability of the cost due to a higher degree of customization.

2.3.1 Residential PV System < 5-10 kW

Table 10: Cost breakdown for a residential PV system – local currency (without VAT)

Cost Category	Average (local currency/W)	Low (local currency/W)	High (local currency/W)
Hardware			
Module	0.75	0.60	1.10
Inverter	0.25 – 0.50		
Other (racking, wiring, etc.)	0.25 – 0.60		
Soft cost			
Installation Labour	0.60 – 1.0		
Customer acquisition	5 - 10% of overall cost		
Profit	5 - 10% of overall cost		
Other (certification, inspection, permitting)	3 - 5% of overall cost		
Subtotal Hardware	1.70	1.10	2.20
Subtotal - Soft cost	1.40	1.10	1.80
Total Installed Cost*	3.10	2.20	4.00

*excluding engineering cost

2.3.2 Utility-scale PV systems > 1 MW (roof top)

Table 11: Cost breakdown for an utility-scale PV system – local currency (CHF)

Cost Category	Average (local currency/W)	Low (local currency/W)	High (local currency/W)
Hardware			
Module	0.45	0.40	0.50
Inverter	0.10 – 0.15		
Other (racking, wiring, etc.)	0.15 – 0.25		
Soft cost			
Installation Labour	0.20 – 0.35		
Customer acquisition	5% of overall cost		
Profit	-		
Other (contracting, permitting, financing etc.)	Very small		
Subtotal Hardware	0.80	0.65	0.90
Subtotal - Soft cost	0.30	0.25	0.40
Total Installed Cost*	1.10	0.90	1.35

*excluding engineering cost

2.4 Financial Parameters and specific financing programs

Bankability of PV systems is changing since more and more installations are not secured by a guaranteed feed-in tariff but operate in a self-consumption mode with varying buy-back tariffs of the surplus by the DSO. Banks are looking into new products adapted to the changing market situation.

Table 12: PV financing scheme

Average rate of loans – residential installations	0.9 – 1.9 % (if secured by mortgage)
Average rate of loans – commercial installations	1.2 - 3.8 %*
Average cost of capital – industrial and ground-mounted installations	1.2 – 3.8%*

* Depending upon secured/unsecured + specifics of the project

2.5 Specific investments programs

Table 13: Specific investment programs

Third Party Ownership (no investment)	More and more companies and utilities offer contracting solutions for PV, either with a fixed contractual percentage of self-consumption (risk bared by the user) or without (risk bared by the investor)
Renting	N/A
Leasing	Various business models are explored including leasing options.
Financing through utilities	Utilities are getting more active in the PV business. They finance PV installations either for their own portfolio or as contracting solutions for end-consumers. They are actively integrating PV in their business, including buying PV installation companies.
Investment in PV plants against free electricity	Some utilities still offer this possibility (investment per m2 of modules, production corresponding to the investment is deduced from the electricity bill) but it is mostly against PV green certificates.
Crowdfunding (investment in PV plants)	Similar as above but usually only for green certificates, niche market
Community solar	Growing (and expected to grow further with the new possibilities of collective self-consumption introduced in 2018) Another possibility are cooperatives that invest in PV plants and repay the invested capital with a small dividend based on the annual performance.

2.6 Additional Country information

Table 14: Country information

Retail Electricity Prices for a household (range)	16 -27 ct/kWh (average = 20.1 ct/kWh)*
Retail Electricity Prices for a commercial company (range)	11-21 ct/kWh*
Retail Electricity Prices for an industrial company (range)	10-21 ct/kWh*
Population at the end of 2017 (or latest known)	8.5 million
Country size (km^2)	41 285
Average PV yield (according to the current PV development in the country) in kWh/kWp	970 kWh/kWp
Name and market share of major electric utilities.	Approx. 650 distributions

* including energy, grid and various regional and national taxes

3 POLICY FRAMEWORK

This chapter describes the support policies aiming directly or indirectly to drive the development of PV. Direct support policies have a direct influence on PV development by incentivizing or simplifying or defining adequate policies. Indirect support policies change the regulatory environment in a way that can push PV development.

3.1 Direct support policies for PV installations

3.1.1 New, existing or phased out measures in 2017

3.1.1.1 Climate change Commitments

Switzerland ratified the Paris Agreement on 6 October 2017. It has therefore committed to an emissions reduction target of minus 50% by 2030 in comparison with 1990 levels, with partial counting of its emissions reductions abroad. In addition, Switzerland has also declared an indicative total reduction target of minus 70 to 85% by 2050 compared with 1990 levels, also with partial counting of emission reductions abroad.

The binding framework for the necessary measures is provided by the CO_2 Act, which is currently being revised and will replace the current regulation (2013) by early 2021. The CO_2 Act provides instruments for reducing emissions in the sector of **transportation** (CO_2 emission regulations for newly registered passenger cars, compensation of 10% of the CO_2 emissions caused by traffic using domestic measures), **buildings** (CO_2 levy on fossil thermal fuels and support measures for renovation of old buildings and transition to renewable energy sources) and **industry** (allocation of emission allowances and establishment of reduction commitments).

Even though none of the measures explicitly include photovoltaics, replacement of fossil fuels in the transportation and building sectors will necessarily be achieved by a partial electrification of these sectors and as a result increase the demand for domestically produced renewable energy. Switzerland's climate change commitments are therefore linked to the 2050 Energy Strategy and the renewable energy targets therein.

3.1.1.2 Description of support measures (excluding BIPV, VIPV and rural electrification)

On a national level there are two main support measures:

- One-time remuneration (direct subsidies) for installations between 2 kW_{DC} and 30 kW_{DC} covering a maximum of 30% of the initial investment. This support scheme was introduced in 2014.
- Feed-in tariffs for installations larger than 10 kW_{DC}. This support measure was introduced in 2009 (another support scheme called "Mehrkostenfinanzierung" existed before). Due to limited funding, there exists currently a long waiting list of over 35'000 projects.

Both support measures are financed through a levy on the electricity consumption. In 2017, this network surcharge was increased from 1.3 ct/kWh to 1.5 ct/kWh.

In 2017, the following subsidies applied on a national level for building attached PV:

Feed-in tariffs as a function of commissioning date (in local currency)

	1.10.2016-31.3.2017	**1.4.2017-30.9.2017**	**From 1.10.2017 onwards**
BAPV < 30 kW	19.0 ct/kWh	16.3 ct/kWh	13.7 ct/kWh
BAPV <100 kW	15.6 ct/kWh	14.6 ct/kWh	13.7 ct/kWh
BAPV <1000 kW	15.2 ct/kWh	14.4 ct/kWh	13.7 ct/kWh
BAPV >1000 kW	15.3 ct/kWh	14.5 ct/kWh	13.7 ct/kWh

One-time remuneration (only for installations < 30 kW) as a function of commissioning date:

BAPV	**1.10.2015-31.3.2017**	**1.4.2017-31.3.2018**
Base contribution	1'400 CHF	1'400 CHF
Additional contribution per kW	500 CHF	450 CHF

3.1.1.3 BIPV development measures

Both, the feed-in tariff and the one-time remuneration scheme offer a premium of approximately 15% for building-integrated PV installations smaller than 100 kW (from 2018 onwards, this premium will be given only for one-time remuneration).

In 2017, the following subsidies applied on a national level:

Feed-in tariffs as a function of commissioning date (in local currency)

	1.4.2016-31.3.2017	**1.4.2017-30.9.2017**	**From 1.10.2017 onwards**
BIPV < 30 kW	21.9 ct/kWh	18.7 ct/kWh	15.8 ct/kWh
BIPV < 100 kW	17.9 ct/kWh	16.8 ct/kWh	15.8 ct/kWh

One-time remuneration (only for installations < 30 kW) as a function of commissioning date:

BIPV	**1.10.2015-31.3.2017**	**1.4.2017-31.3.2018**
Base contribution	1'800 CHF	1'600 CHF
Additional contribution per kW	610 CHF	520 CHF

In addition to the federal subsidies for BIPV, some communities give also incentives for PV at façades (e.g. bonus of 50% compared to roof-top).

In addition, several innovative BIPV projects (such as using specifically designed modules for protected buildings or resulting in energy self-sufficient buildings) have been supported by a special fund for pilot and demonstrator projects from the government.

3.1.1.4 Utility-scale measures including floating and agricultural PV

No specific utility-scale measures are in place in Switzerland. One floating pilot plant on a high-altitude mountain lake is under development.

3.1.1.5 Rural electrification measures

No specific rural electrification measures are in place in Switzerland.

3.1.1.6 Support for electricity storage and demand response measures

There is no support scheme for electricity storage on a national level, however there are currently three cantons (Thurgau, Appenzell Ausserrhoden and Vaud) that have introduced direct subsidies for local storage solutions and it is expected that other cantons will follow.

In canton Vaud, 1 mio Swiss francs were allocated for single household storage solutions and 1.5mio Swiss francs for industrial storage solutions. The support scheme was limited to 2017, was covering maximum 35% of the investment cost and came with certain conditions (back-up solution in case of power outage and minimum self-sufficiency of 40-50% for single households and a load management system for industries).

Some municipalities give additional subsidies corresponding to around 10% of the investment cost.

The situation regarding tax deduction is unfortunately different from one canton to another. In most canton, the investment in batteries for increased self-consumption can be deducted if installed at the same time as the PV installation. Others allow to deduct it even if installed later.

There are ongoing discussions of some DSO for introducing new tariff designs that would allow for partial recovery of the investment costs if the owner of the storage system is willing to let the DSO party manage the storage unit. More and more utilities are also offering solutions for virtual storage. For a fee (fixed or per kWh) the owner of a PV system can use the DSOs grid as a virtual storage for his PV production and use it at a later stage (basically a net-metering solution).

There are also companies on the market (e.g. Ampard) that aggregate several individual storage units into virtual power plants. Such storage swarms can then be used, for instance, to sell primary control capacity to the grid operators, therefore generating an additional revenue for the owner of the storage unit.

3.1.1.7 Support for electric vehicles (and VIPV)

There is no direct national support scheme for electric vehicles in Switzerland.

Fully electric vehicles do not pay the automobile duty of 4% and of course, since they do not run on fossil fuels, there is not petroleum tax to pay (as such, EVs do currently not contribute to road infrastructure). Electrical vehicles also often pay reduced vehicle taxes, but there are large differences from one canton to another.

The Swiss Government has recently (11 September 2018) launched a tender for the installation of fast charging stations on 100 service stations along motorways. Grid connection will be pre-financed by the government and repaid by the operator through concession fees.

Some communities give financial incentives for the installation of local charging stations (e.g. 20% subsidy). Since 2017, Swiss eMobility (Swiss Association for Electric Mobility) awards each year a prize (golden plug) to communities and cities with exceptional effort to push electromobility.

Table 15: PV support measures (summary table)

	On-going measures residential	Measures that commenced during 2017 - residential	On-going measures Commercial + industrial	Measures that commenced during 2017 – commercial + industrial	On-going measures Ground-mounted, including floating	Measures that commenced during 2017 – ground mounted, including floating
Feed-in tariffs	Prices depend on the local DSO Generally above market price		Prices depend on the local DSO Generally above market price		Prices depend on the local DSO Generally above market price	
Feed-in premium (above market price)	Yes, but with cap, huge waiting list		Yes, but with cap, huge waiting list		Yes, but with cap, huge waiting list	

Capital subsidies	Yes, up to 30 kW_{DC}, max. 30% of investment cost		Yes, up to 30 kW_{DC}, max. 30% of investment cost		Yes, up to 30 kW_{DC}, max. 30% of investment cost	
Green certificates	Most utilities pay between 0.8-5 ct/kWh for green certificates (so-called guarantee of origin)		Most utilities pay between 0.8-5 ct/kWh for green certificates (so-called guarantee of origin)		Most utilities pay between 0.8-5 ct/kWh for green certificates (so-called guarantee of origin)	
Renewable portfolio standards (RPS) with/without PV requirements	None		None		None	
Income tax credits	Cost for PV system is deductible for house owners				-	
Self-consumption	Allowed and encouraged		Allowed and encouraged		Allowed and encouraged	
Net-metering	Few utilities		Few utilities		Few utilities	
Net-billing	Few utilities		Few utilities		Few utilities	
Collective self-consumption and virtual net-metering	Allowed if in the same building	Will be extended in 2018	Allowed if in the same building	Will be extended in 2018		
Commercial bank activities e.g. green mortgages promoting PV	Few		Few		Few	
Activities of electricity utility businesses	Utilities engage more and more in PV. Some have their own installation subsidiaries, others promote PV with attractive schemes for storing surplus production or through contracting solutions.					
Sustainable building requirements		Some cantons have already implemented into their		Some cantons have already implemented into their		

		cantonal energy acts the requirement that new constructions must install 10W PV per square meter of heated area		cantonal energy acts the requirement that new constructions must install 10W PV per square meter of heated area		
BIPV incentives	Yes		Yes		-	
Storage		Some cantons started to subsidize local storage units		Some cantons started to subsidize local storage units		

3.2 Self-consumption measures

Table 16: Self-Consumption Schemes

PV self-consumption	1	Right to self-consume	Yes, since 2014
	2	Revenues from self-consumed PV	Savings on electricity bill (2-3 times higher than feed-in tariffs)
	3	Charges to finance Transmission & Distribution grids	No, some DSO charge for installing a bi-directional energy meter
Excess PV electricity	4	Revenues from excess PV electricity injected into the grid	Depending on DSO (range of 5-15 ct/kWh, average around 10ct/kWh) http://www.vese.ch/pvtarif/
	5	Maximum timeframe for compensation of fluxes	15 minutes
	6	Geographical compensation	None
Other characteristics	7	Regulatory scheme duration	Not defined
	8	Third party ownership accepted	Yes
	9	Grid codes and/or additional taxes/fees impacting the revenues of the prosumer	Some utilities applied a different tariff structure for prosumers (power metering). From 2018 onward, only one tariff structure will be allowed for consumers with a grid connection < 30 kVA
	10	Regulations on enablers of self-consumption (storage, DSM…)	In certain cases, heat pumps or resistive heating systems are remotely controlled by the DSO, but not necessarily in a way that optimizes self-consumption. DSM is common for industries to avoid power peaks, but can be used to optimize self-consumption as well. Thanks to more solutions available for DSM, more and more single household owners with PV

			systems take an interest in those in order to increase self-consumption. Specific recommendations exist for connection and metering of storage systems.
	11	PV system size limitations	No PV size limitations
	12	Electricity system limitations	None
	13	Additional features	None

3.3 Collective self-consumption, community solar and similar measures

Collective self-consumption has been allowed by most DSOs, as long as the consumers are in the same building or within the same perimeter of land. Each consumer remained client of the DSO and received the electricity bill from him. Some DSOs have proposed to buy-back the entire PV production (based on a production meter) at two different tariffs (one tariff for the injected and one tariff for the self-consumed electricity) while other DSOs are doing virtual net-metering, as long as the public grid is not used. In 2017, they were still a lot a difference in the DSOs proposals for collective self-consumption.

With the new legislation that has come into force on January 2018, the possibilities for collective self-consumption will be improved significantly and every DSO have to approve it. It will be allowed to extend self-consumption to neighbouring buildings, as long as their land is contiguous and that the public grid is not used (one single grid connection). The consumers that group together will be treated as one single consumer (internal metering will be under the responsibility of the group) for the DSO and can have access to the free electricity market (additional strong incentive).

3.4 Tenders, auctions & similar schemes

There are no tendering schemes for PV systems in Switzerland.

There are however several auction platforms for selling/buying green certificates (guarantee of origin). The price for those certificates has constantly dropped over the past years.

3.5 Financing and cost of support measures

National PV incentives (one-time remuneration and feed-in tariff) are financed by a network surcharge which is paid on a kWh-basis by all electricity consumers. Under certain conditions, companies for which electricity cost exceeds 10% of their gross value can be reimbursed (large consumers).

On January 2017, the network surcharge has been increased from 1.3 ct/kWh to 1.5 ct/kWh. This corresponds to a burden of 67.5 Swiss francs per year for an average household with a consumption of 4’500 kWh. Following the acceptance of the new energy act in May 2017, the network surcharge has been increased to 2.3 ct/kWh on January 2018.

In 2017, the following amount has been paid for the two incentive measures:

- One-time remuneration: 102 mio Swiss francs
- Feed-in tariffs: 149 mio Swiss francs

Due to a huge waiting list for national feed-in tariffs and (up to May 2017) an uncertainty regarding future funding, no additional quota for feed-in tariffs were released in 2017.

3.6 Indirect policy issues

Minergie, a leading building standard organization, supported by the cantons as well as the Swiss Federal Office of Energy and the building industry, revised its building standards in 2016. PV has become quasi-mandatory to fulfil the requirements for the nearly zero energy standards. Since for a Minergy labelled building, only 40% of the grid-injected electricity can be counted for the overall energy requirements, there is an additional incentive to optimize self-consumption (DSM, battery).

These voluntary building standards helped to pave the way for the coming new building standards defined by the cantons (10 Watt PV per square meter of heated area in new buildings).

Since 2015, the Swiss government has published a recommendation for the energy policies in cantons. These regulations should include a requirement for PV in every new building. In some cantons (e.g. Vaud), requirement of including about 10 W PV per square meter of heated area for new buildings is already implemented, others are expected to adapt their cantonal energy acts accordingly in the coming years. It is also recommended to include 10% renewable energy when the heating system has to be retrofitted. PV can be an option among others.

4 INDUSTRY

4.1 Production of feedstocks, ingots and wafers (crystalline silicon industry)

There is no feedstock, ingots and wafers production in Switzerland

4.2 Production of photovoltaic cells and modules (including TF and CPV)

Module manufacturing is defined as the industry where the process of the production of PV modules (the encapsulation) is done. A company may also be involved in the production of ingots, wafers or the processing of cells, in addition to fabricating the modules with frames, junction boxes etc. The manufacturing of modules may only be counted to a country if the encapsulation takes place in that country.

Total PV cell and module manufacture together with production capacity information is summarised in Table 18 below.

Table 18: Production and production capacity information for 2017

Cell/Module manufacturer (or total national production)	**Technology** (sc-Si, mc-Si, a-Si, CdTe)	**Total Production (MW)**		**Maximum production capacity (MW/yr)**	
		Cell	Module	Cell	Module
Wafer-based PV manufactures					
Meyer Burger	sc-Si, mc-Si	0	12 MW	0	220 MW
	PVT hybrid		200 kW		N/A
	bifacial		200 kW		N/A
Megasol*	sc-Si, mc-Si	0	No data provided	0	80 MW*
Thin film manufacturers					
Flisom	Flexible CIGS		No data provided		*15 MW pilot line*
TOTALS			**12 MW**		**355 MW**

* Megasol did not provide any data on total production and production capacity. The production capacity stated is based on information found on their homepage. Since Megasol has increased their production capacity end of 2016 to approx. 80 MW, it can be assumed that their total production in 2017 was significantly higher than the 20 MW provided in 2016.

a) There is no cell production in Switzerland, except for pilot lines for new technologies such as SmartWire connection Technology SWCT (Meyer Burger) or CIGS (Flisom)

b) Swiss manufactures are specialised in BIPV products. Meyer Burger produces its famous Megaslate module as well as hybrid (PV and solar thermal) collectors, while Megasol produces at their manufacturing site in Switzerland custom-made special modules (size, shape and colour).

c) Megasol has also a production facility of 120 MW capacity in Ningbo, China, for standard high performance modules

4.3 Manufacturers and suppliers of other components

Switzerland has a strong industry for BOS-components. Among them are the following companies:

Inverters:

Studer Innotec manufactures inverters and chargers for stand-alone and storage solutions, mostly for remote sites without grid access all over the world.

Junction Boxes/Connectors:

Stäubli Electrical Connectors (former Multi Contact AG) is the leading manufacturer of cables and connectors for PV Systems. They claim that over 200 GW of PV is connected using their connectors and to have market share of 50% with module connectors.

Cables:

Huber & Suhner and Heiniger AG have been offering a variety of dedicated PV cables for several decades.

Supporting Structures:

Montavent offers mounting systems for profiled metal and corrugated roofs.

ALUSTAND has mounting structures for tilted and flat roofs.

Ernst Schweizer produces in-roof mounting systems (Solrif) as well as structures for flat and pitched roofs. They also produce solar thermal collectors for roof-top and façade applications.

Storage Batteries:

Leclanché develops and produces energy storage systems with large format lithium-ion cells and has specialised on storage systems based on Lithium titanate technology.

Components for customized PV modules:

Solaxess develops a nanotechnology-based film for producing white and coloured solar panels without visible cells or connections

SwissInso produces coloured solar glass (Kromatix ^{TM}) by plasma processes for Building integrated PV

5 PV IN THE ECONOMY

5.1 Labour places

Table 19: Estimated PV-related labour places in 2017

Research and development (not including companies)	200
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	4 400*
Distributors of PV products	
System and installation companies	
Electricity utility businesses and government	400 (estimated)
Other including maintenance	500*
Total	5 500

5.2 Business value

Business values are based on internet research – annual reports of listed companies, market calculations and added value estimates of the installations.

Table 20: Value of PV business

Sub-market	**Capacity installed *in 2017* (MW)**	**Price per W (CHF)** *(from table 7)*	**Value (million CHF)**	**Totals (million CHF)**
Off-grid domestic and non-domestic	0.4	*13*	*5*	
Grid-connected distributed & centralized	242	2.05*	*496*	
				501
Export of PV products				*396*
Change in stocks held				-
Import of PV products				*157*
Value of PV business				***740***

*Compared to 2016, the average price per W was slightly increased despite a general downwards trend in PV cost. The reason being the shift towards smaller installations.

6 INTEREST FROM ELECTRICITY STAKEHOLDERS

6.1 Structure of the electricity system

The electricity system in Switzerland is organised on 7 network levels, from the high-voltage transmission network (level 1) down to the low-voltage distribution to the end-consumer (level 7).

Swissgrid is that national transmission grid operator at level 1 (comprising of 380 kV and 220 kV transmission lines) and is responsible for grid stability and frequency control.

Switzerland's supply of electricity to end users is secured by more than 650 DSO companies. Many of them are also responsible for supplying water and gas. In some cantons and municipalities, a single vertically integrated company is responsible for these supply tasks, while in other cantons a variety of companies share this responsibility. Some of the utilities may have only a few hundred of customers, while others have more than 100'000 customers.

In terms of grid-interconnection of PV, there are national regulations and recommendations, but each DSO may have its specific technical interconnection conditions. There is however a tendency for harmonisation and simplification, both in administrative and technical terms.

DSOs are required to accept electricity from a PV power plant up to 3'000 MWh per year and there is a minimal tariff that has to be paid, calculated based on the DSOs procurement and generation cost.

6.2 Interest from electricity utility businesses

An increasing numbers of electricity utilities are entering the PV business. Especially larger utilities that have their own (non-solar) electricity production facilities have been under increasing financial pressure, due to falling electricity prices on the European market, and are therefore expanding their business activities. Due to the private-public status of most of the utilities (they are typically owned by the communities and the cantons) this development is not always well seen by the traditional PV installing companies

The following PV business models are implemented by electricity utilities

- Investment in their own PV plants for their production portfolio
- Establishment of subsidiary units for engineering and installation services (sometimes including acquisition of PV installations companies)
- Offering contracting solutions for PV power plants, selling the PV electricity to the end-consumer
- Providing services for metering and billing within the newly possible (from 2018 onwards) self-consumption communities
- Virtual battery solutions, batteries on district level and EV charging stations

In order to intensify the exchange between the traditional solar sector (represented by Swissolar, the professional association) and the traditional grid stakeholders (represented by VSE/AES, the Swiss utility association), experts from both sectors meet regularly in working groups in order to revise recommendations for grid connections, metering requirements, battery exploitation schemes, etc.

6.3 Interest from municipalities and local governments

Municipalities and cities are key stakeholders in pushing the development of PV in their jurisdiction. On the one hand, they becoming more and more aware of their own huge potential (on infrastructure owned by the local government such as schools, public buildings, etc.) and therefore invest themselves in PV power plants. On the other hand, they can create favorable conditions (simplified administrative procedures, for example) and grant additional local subsidies for solar, storage or EV in order to push the development.

There is a label called “Energy City” and “Energy Municipality” which is awarded to cities and municipalities that live and implement a sustainable municipal energy policy. Energy cities promote renewable energies, environmentally friendly mobility and rely on the efficient use of resources.

One example is the canton of Geneva that has set the target to produce 100 GWh of PV electricity by 2025.

7 HIGHLIGHTS AND PROSPECTS

Excerpt from the IEA PVPS Annual Report 2017, edited by Stefan Nowak, Switzerland IEA PVPS Chairman:

"In 2017, more than 60 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. In the field of solar cell research, priorities lie on heterojunction structures and passivating contacts for high-efficiency crystalline silicon solar cells as well as on different thin-film solar cell technologies for building integration, in particular CIGS cells. 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. Work at the Swiss Federal Institute of Technology (EPFL) and the CSEM PV Technology Centre in Neuchâtel have focussed on heterojunction and passivating contacts for high-efficiency crystalline silicon solar cells. As part of the activities related to passivating contacts, new process steps (e.g. thermal annealing and selective front side contacts) compatible with industry practice were successfully explored. On the more fundamental R&D side, in a recent project on perovskite / silicon heterojunction tandem structures, 22,7 % monolithic tandem cells and 25,6 % 4-terminal tandem cells were achieved.

Another highlight of the photovoltaic research at CSEM in Neuchâtel in collaboration with the NREL in the United States was the demonstration of a new one-sun record conversion for tandem solar cells of 32,8 % achieved with a gallium indium phosphide / crystalline silicon solar cell. 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 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. The work aimed for development of novel strategies to reduce non-radiative recombination mechanism in order to improve the photovoltaic parameters in CIGS solar cells towards 25 % power conversion efficiency. To do so, novel passivation strategies for bulk and especially interfaces have been explored. On the way towards industrial implementation of flexible CIGS solar cells, cooperation continued with the company Flisom which is commissioning a 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. 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 2017. Using coloured, crystalline silicon-based modules, PV systems in heritage protected zones are starting to be realised (front picture), thereby providing opportunities for applications in critical zones. As part of the analysis of such systems, the losses in energy yield using different technologies to create the colour appearance are being assessed.

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 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 developed 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. During 2017, all Universities of Applied Sciences with PV related activities have met in a workshop to explore cooperation opportunities, in view of strengthening the applied research base from components to systems and applications."

An important milestone regrading integration of PV into historic protected sites has been reached in the village of Ecuvillens, located in the Swiss canton of Fribourg. Terracotta-red solar panels, developed by CSEM (Swiss center for microelectronics and microtechnologies) and ISSOL Suisse have been installed on the roof of a farmhouse, allowing the farmhouse to fully retain its original character. This pilot project was made possible thanks to the relevant government agencies (the Department of Energy and the Department of Cultural Property) and the support provided by the Swiss Federal Office of Energy (SFOE) and ÜserHuus, as well as the commitment of various partners https://www.csem.ch/page.aspx?pid=47346).

The most important change in 2017 on the political level has been the acceptance of the new Energy Act by the Swiss voters on May 21. It includes the following three main targets:

- to increase energy efficiency in buildings, mobility, industry and appliances
- to increase the use of renewable energy by improving the legal framework and by promotion
- to put a ban on new generation licences for nuclear power plants

The declared target for domestic production of renewable energy (excluding hydropower) is 11'400 GWh by 2035, corresponding to approximately 20% of the domestic electricity consumption. However, in study commissioned by Swissolar (Swiss Solar Professional Association) and realised by Meteotest in 2017, the technical & economical feasible and socially acceptable potential for PV alone (roofs and façades) has been assessed at 30 TWh, corresponding to approximately 50% of todays electricity consumption (https://tinyurl.com/y7djh8hq, study in German only).

The new legislation has been in force since 1 January 2018.

Further details on the Swiss Energy Strategy 2050 can be found via the following link:

http://www.bfe.admin.ch/energiestrategie2050/index.html?lang=en