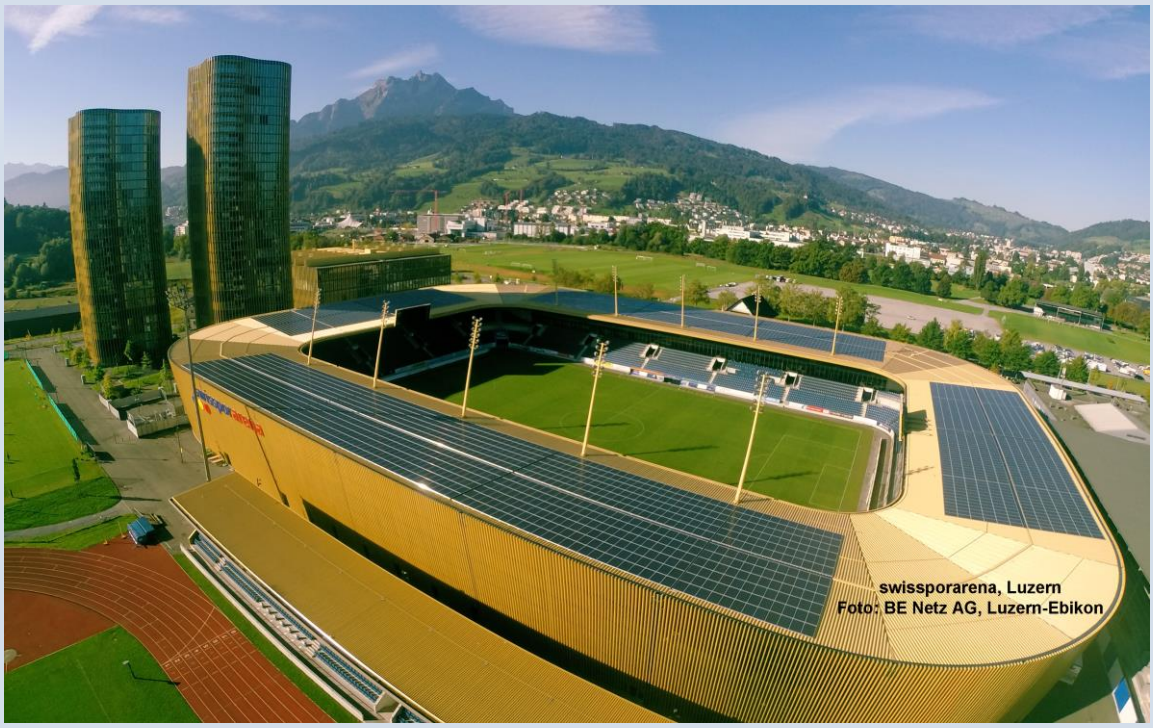
IEA INTERNATIONAL ENERGY AGENCY

National Survey Report of PV Power Applications in Switzerland 2016



PVPS

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

Prepared by
Pius Hüsser, Nova Energie GmbH, July 2017
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 TCP) 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 web-site.

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 Switzerland's National Survey Report for the year 2016. 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 system market is defined as the market of all nationally installed (terrestrial) PV applications with a PV capacity of 40 W or more. A PV system consists of modules, inverters, batteries and all installation and control components for modules, inverters and batteries. 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 2016 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2016, although commissioning may have taken place at a later date.

1.1 Applications for Photovoltaics

In 2016, the Swiss market decreased by 20% from a record level of >330 MW, down to 270 MW.
Although this is, on a per capita basis, still remarkably high with 33 W/capita, the Swiss market was among the highest in Europe in 2016. However, the limitations of new funding for the supporting framework with feed-in-tariffs (FiT) and direct subsidies had a negative effect on the market. Since only small installations below 30 kW_{DC} have still a guaranteed right for direct subsidies, the market for larger systems is drying out.
Nevertheless, since the referendum in May 2017 when the Swiss voted for new support schemes for renewables and put a ban on new nuclear power plants, the market outlook for Switzerland is promising.
The installed capacity of 1,66 GW by the end of 2016 will produce approximately 2,8 % of Switzerland's electricity demand in 2017.
Self-consumption is now the main driver for residential, as well as commercial sized systems. Depending on tariff conditions for grid costs as well as energy buy-back tariffs, some DSO allow the operation of PV systems to be profitable for the time being.

Swissporarena, Lucerne
1,1MWp
Engineering, Installation &
Photo: BE NETZ AG,
Lucerne

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 2016*".
About 90% of installers, importers/distributers and manufacturers are covered in this annual market survey.
The accuracy of the data is estimated to be rather high, better than +/- 10%. This has been approved in 2015 and for previous years with the WTO import / export statistics of solar panels.

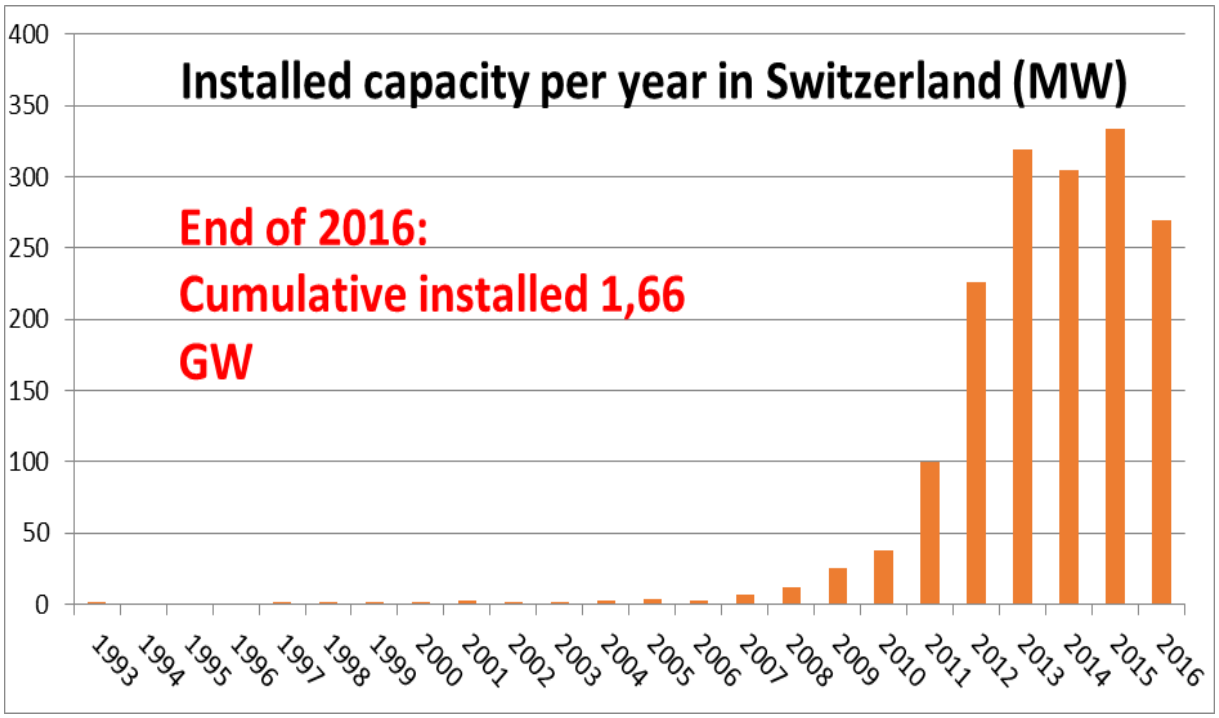

Table 1: PV Power Installed during Calendar Year 2016

AC			MW installed in 2016	MW installed in 2016	AC or DC
Grid-connected	BAPV	Residential <30kWp	250 MW	Approx. 50 MW	DC
		Commercial 30 - 250kWp		Approx. 160 MW	DC
		Industrial >250 kWp		Approx. 40 MW	DC
	BIPV	Residential	20 MW	15 MW	DC
		Commercial		5 MW	DC
		Industrial			
	Ground-mounted	cSi and TF	< 1 MW	< 1 MW	DC
		CPV			
Off-grid		Residential	0		
		Other	200 kWp		DC
		Hybrid systems			
		Total	270 MW		DC

Table 2a: PV Power Installed during Calendar Year 2016 – System Size

From the market survey 2016, the following numbers of installations where reported:

System Size (kW)	Numbers of Systems 2016	Capacity Installed 2016 (kW)
<4	960	2 610
4 - 20	5 895	54 884
20 - 50	1 318	37 822
50 - 100	290	180
>100	445	147 789
Size unknown	*392*	*6 700*
Total*	***Approx. 9 300***	***270 000***

* *Markterhebung Sonnenenergie 2016*, June 2017, Swiss Federal Office of Energy

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.

Table 2b: Data Collection Process

<table>
<tr><td>Data are collected in DC</td><td></td></tr>
<tr><td>

- The data collection process is done by Swissolar 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 report has been published by the Swiss Federal Office of Energy in June 2016 and also serves as a basis for the annual renewable energy statistics.

</td><td>  </td></tr>
<tr><td>Link to the Swiss Federal Office of Energy www.bfe.admin.ch

Electricity Statistics 2016 (DE/FR):
http://www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=de&name=de_306571764.pdf

Overall Energy Statistics 2015:
http://www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=de&name=de_83041321.pdf</td><td> 
</td></tr>
<tr><td colspan="2">The quality and accuracy of the data is expected to be better than +- 10%.</td></tr>
</table>

In 2016, the Swiss utility AXPO commissioned the new Linth-Limmern pumped storage hydropower station with a capacity of 1 GW.

Table 3: PV Power and the Broader National Energy Market

MW-GW for Capacities and GWh-TWh for Energy	2016 Numbers	2015 Numbers	2014 Numbers	2013 Numbers
Total power generation capacities (all technologies)	Approx. 20,9 GW	Approx. 19,6 GW	Approx. *19,1 GW*	Approx. 18,7 GW
Max. power demand	*12 489 MW*	*12 924 MW*		
Total power generation capacities (renewables including hydropower)	Approx. 16,9 GW	Approx. 15,6 GW	Approx. 15,1 GW	Approx. 14,7 GW
Total electricity demand (= consumption)	58,24 TWh	58,2 TWh	57,5 TWh	59,3 TWh
New power generation capacities installed during the year (all technologies)	+ 990 MW Hydro, + 270MW PV + 70 MW Wind & Biomass	Approx. 0,5 GW new RES All others: 35 MW	Approx. 0,4 GW RES and very few Co-Generation plants	0,4 GW
New power generation capacities installed during the year (renewables including hydropower)	+ 990 MW Hydro, + 270MW PV + 70 MW Wind & Biomass All others: n/a	Approx. 0,5 GW new RES incl. 330 MW of PV	Approx. 0,4 GW RES very few Co-Generation plants	0,4 GW
Total PV electricity production in GWh-TWh	Approx. 1 333 GWh (5% – 10% less irradiation compared to 2015)	Approx. 1 120 GWh	Approx. 850 GWh	544 GWh
Total PV electricity production as a % of total electricity consumption	2,3%	1,9%	1,4%	0.9 %

Table 4: Other Information

	2016 Numbers*
Number of PV systems in operation in Switzerland (a split per market segment is interesting)	**59 000 approx.**
Capacity of decommissioned PV systems during the year in MW	**<200 kWp, mostly off grid (Stand-alone)**
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%**

* Markterhebung Sonnenenergie 2016, June 2017, Swiss Federal Office of Energy

Table 4: PV Systems - Market Segmentation (Numbers)*

Type of System	2016 Newly Added	2015 Newly Added	2014 Newly Added	2016 Cumulated
Single Family Homes	6 317	6 300	5 136	34 300
Apartment Buildings	834	868	817	5 000
Industrial Buildings	721	957	768	7 900
Farm Houses	608	1 216	987	7 100
Commercial Buildings	110	153	168	900
Municipal & State Owned Buildings	244	343	280	2 840
Traffic Infrastructure and Buildings	13	2	23	100
Others	453	59	2	860
Total	**9 300**	**9 898**	**8 181**	**59 000**

*These numbers are part of the "*Markterhebung Sonnenenergie 2016" and earlier years'* statistics but there is some uncertainty in the quality of the reported data.

Table 5: The Cumulative Installed PV Power in 4 Sub-markets

	Cumulative Installed Capacity DC as of 31 December (kW)																						
Sub-market	1992	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Stand-alone Domestic	1 540	1 780	1 940	2 030	2 140	2 210	2 300*	2 390	2 480*	2 570	2 740	2 810	2 930	3 050	3 200	3 800	4 000	4 100	4 200	4 MW	4 MW	4 MW	4 MW	4 MW
Stand-alone Non-domestic	70	112	143	162	184	190	200	210	220	230	260	290	320	350	400									
Grid-connected Distrib-uted	2200	3 600	4 050	4 850	5 950	7 630	9 420	11 220	13 340	15 140	16 440	18 440	21 240	23 740	30 040	41 540	67 040	104 140	206 700	433 MW	752MW	1 057 MW	1 390 MW	1 660 MW
Grid-connected Central-ized	900	1 200	1 350	1 350	1 450	1 470	1 480	1 480	1 560	1 560	1 560	1 560	2 560	2 560	2 560	2 560	2 560	2 560						
TOTAL (kW)	4 710	6 692	7 483	8 392	9 724	11 500	13 400	15 300	17 600	19 500	21 000	23 100	27 050	29 700	36 200	47 900	73 600	110 900	211 100	437 MW	756 MW	1 061 MW	1 394 MW	1 664 MW

- Swiss PV market decreased by 20% in 2016 to 270 MW newly installed capacity (32 W/capita).
- Besides one large roof mounted system (5MW) the market shifted again towards smaller installations due to the direct subsidies only eligible for system sizes below 30 kW(DC).

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module Prices

The module and system prices in Switzerland follow the global market development. The market is quite competitive. Some of the big players/installers purchase part of their modules, inverters and support material on the European continent and even directly from China. Thus, also the importers/distributors in Switzerland need to offer competitive prizes for the smaller installers; otherwise they source their main needs from abroad.

Table 6: Typical Module Prices for a Number of Years

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015[1]	2016
Standard module price for small systems in the range of 3 to 10 kWp	4.80	5.20	5.00	5.00	3.80	3.60	2.50	1.30*	1.00*	0.95*	0.90*	0.80**
Avarage price, large systems (> 100 kWp)	4.60	5.00	4.80	4.80	3.30	2.20	1.30	0.85*	0.80*	0.57**	0.55**	0.50**

[1] Positive effect on costs due to stronger Swiss currency
*Source: Der Photovoltaik-Markt: Marktbeobachtung 2016, February 2016, Bundesamt für Energie (Swiss Federal Office of Energy)
** Estimation based on several offerings for small and large systems in 2016

2.2 System Prices

A summary of typical system prices is provided in the following tables.

Table 7: **Turnkey Prices of Typical Applications – Local Currency**

Category/Size	Typical Applications and Brief Details	Current Prices per W (CHF)
OFF-GRID Up to 1 kW	Holiday houses, traffic control and many other applications	5.00 to 12.00
OFF-GRID >1 kW	Alpine huts, alpine dairies Maximum size for large alpine huts in the range of 10 to 20 kW	4.00 to 12.00
Grid-connected rooftop; up to 10 kW (residential)	Roof mounted (BAPV)	2.50 to 3.50*
Grid-connected rooftop; from 10 to 250 kW (commercial)	Roof mounted (BAPV)	1.50 to 2.50*
Grid-connected rooftop; above 250kW (industrial)	Industry or public buildings (BAPV)	1.25– 1.70*
Grid-connected ground-mounted above 1 MW	No market in Switzerland	n/a
Other category (hybrid diesel-PV, hybrid with battery, etc.)	Hybrid system with hybrid modules (PV and solar thermal).	n/a (Pilot stage)

* Estimation based on several offerings for small and large systems in 2016

Table 8: National Trends in System Prices (Current) for Different Applications – Swiss Francs/CHF

YEAR	1992	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
10-20 kW	13.00	11.80	9.90	8.5	9.00	9.10	8.70	7.25	6.50	4.5	3.50	3.25	2.50 - 3.50	2.20 – 3.50	2.00 – 3.50
3-4 kW	13.40	12.80	12.50	10.00	10.0	9.65	9.80	8.80	7.00	6.50	5.00	4.50	4.00 - 5.00	3.00 – 5.00	3.00 – 5.00

The standard size for single family houses increased considerably in the last few years to a range of 5 to 15 kW. The specific costs for systems of 3 kW or less thus remained comparatively high due to fixed costs, such as administration (grid connection), security issues while working on a roof, etc. The direct subsidy scheme for installations up to 30 kW_{DC} has also a certain effect on prices paid for smaller PV systems (Less pressure on costs).

2.3 Cost Breakdown of PV Installations

This analysis is based on several offerings during 2016.

2.3.1 Residential PV Systems < 10 kW

Table 9: Cost Breakdown for a Residential PV System – Local Currency

Cost Category	Average (CHF/W)	Low (CHF/W)		High (CHF/W)
	Hardware			
Module	0.80	0.60		1.00
Inverter		0.20 - 0.40		
Other (racking, wiring, etc.)		0.20 – 0.60		
	Soft Costs			
Installation		0.40 – 1.00		
Customer Acquisition		5% to 10% of overall costs		
Profit		5% to 10% of overall costs		
Other (permitting, contracting, financing, etc.)		n/a (very small)		
Subtotal Hardware	1.70	1.20		2.00
Subtotal Soft Costs	1.00	0.80		1.50
Total	2.70	2.10		3.50

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

Table 10: Cost Breakdown for a Utility-scale PV System – Local Currency

Cost Category	Average (local Currency/W)	Low (local currency/W)	High (local currency/W)
	Hardware		
Module	0.50	0.45	0.55
Inverter	0.15 - 0.20		
Other (racking, wiring, etc.)	0.15 – 0.30		
	Soft Costs		
Installation	0.25 – 0.45		
Customer Acquisition	5% of overall costs		
Profit	5% of overall costs		
Other (permitting, contracting, financing, etc.)	n/a (very small)		
Subtotal Hardware	0.90	0.75	1.05
Subtotal Soft Costs	0.35	0.30	0.50
Total	1.25	1.05	1.55

2.4 Financial Parameters and Specific Financing Programmes

The financial situation is still unchanged. The “cost” for loans remains at an all-time low. This supports the financing of PV systems for commercial applications, as well.

Table 11: PV Financing Scheme

Average rate of loans – residential installations	0.8% - 1.5 %
Average rate of loans – commercial installations	1% - 3.0 %
Average cost of capital – industrial and ground-mounted installations	1.5% - 5%

2.5 Specific Investment Programmes

Table 11a: Country Information

Third Party Ownership (no investment)	Practically non-existent in Switzerland
Renting	n/a
Leasing	n/a
Financing through utilities	Very small share of the market
Investment in PV plants against free electricity	No market
Crowdfunding (investment in PV plants)	Only a niche market
Other (please specify)	Citizen owned PV systems - Prepaid solar electricity consumption for 20 years –> such as an interest free loan to the utility. Price is fixed for 20 years - Cooperatives founded to build a PV plant; normally, the initiators also promise a small dividend on the invested capital

2.6 Additional Country Information

Table 12: Country Information

	2016	2015	2014	2013	2012
Swiss Average: Retail electricity prices for households, commercial companies and industrial companies; see below (CHF/kWh)	n/a	0.171	0.1695	0.1670	0.1685
Average Consumption per capita (kWh/a)	6 956	7 033	7 018	7 333	7 375
Population (average)	Ca. 8,4 Mio	8,325 Mio	8,238 Mio	8,140 Mio	8,040 Mio
Country Size (km^2)	41 285 km2				
Average PV Yield in kWh/kWp	950	1000	995	975	950
Name and market share of major electric utilities.	Approx. 700 utilities, mostly DSOs, from very small (< 100 customers) to municipality owned utilities, such as ewz (City of Zurich) with their own hydro production and serving > 200 000 customers.				

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 2016

3.1.1.1 Direct Subsidies for Systems < 30 kW_{DC}

The Swiss Federal Council decided in June 2016 to increase the levy on the electricity consumption for 2017 onwards from 1.3 CHFcents/kWh to 1.5CHFcents/kWh.
The measure helped considerably to stabilize the market; especially for systems applying for direct subsidies.

3.1.1.2 BIPV Development Measures

The Swiss FiT and direct subsidy scheme still offer a premium for BIPV installations.
Since there is still a cap on the FiT scheme with a long waiting list, the share of BIPV is decreasing. The premium with direct subsidies is also insufficient in order to drive the residential BIPV market in a considerable manner.

3.1.1.3 Support for Electricity Storage and Demand Response Measures

More and more cantons are willing to introduce direct support schemes for local storage.
Besides this, there are also some DSO who are considering new tariff designs which would allow for the recovery of some of the investment costs for local storage units, if the owner is willing to let the DSO partly manage the storage unit.

Table 13: PV Support Measures

PV Support Measures	On-going measures residential	Measures that commenced during 2016 - residential	On-going measures Commercial + industrial	Measures that commenced during 2016 – commercial + industrial	On-going measures Ground-mounted	Measures that commenced during 2016 – ground mounted
Feed-in tariffs	Different prices depending on local DSO. In average above market price		Different prices depending on local DSO In average above market price		Different prices depending on local DSO In average 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 installation cost, 500 CHF/kWp		Yes. Up to 30 kW_{DC} Max. 30% of installation cost, 500 CHF/kWp		none	

PV Support Measures	On-going measures residential	Measures that commenced during 2016 - residential	On-going measures Commercial + industrial	Measures that commenced during 2016 – commercial + industrial	On-going measures Ground-mounted	Measures that commenced during 2016 – ground mounted
Green certificates	Some utilities	Some utilities	Some utilities	Some utilities	Some utilities	Some utilities
Renewable portfolio standards (RPS) with/without PV requirements	*none*	*none*	*none*	*none*	*none*	*none*
Income tax credits	Yes					
Self-consumption	yes		Yes		yes	
Net-metering	Few utilities		Few utilities		Few utilities	
Net-billing	Few utilities		Few utilities		Few utilities	
Collective self-consumption and virtual net-metering		Under discussion		Under discussion		Under discussion
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, e.g storing and selling back the solar production for an individual producer.					
Sustainable building requirements		The cantons agreed in 2015, that in the future, residential buildings must install 10 W of PV per square meter of heated area		The cantons agreed in 2015, that in the future, commercial buildings must install 10 W of PV per square meter of heated area		
BIPV incentives	yes		yes		yes	

PV Support Measures	On-going measures residential	Measures that commenced during 2016 - residential	On-going measures Commercial + industrial	Measures that commenced during 2016 – commercial + industrial	On-going measures Ground-mounted	Measures that commenced during 2016 – ground mounted
Other		Some cantons start to subsidize local storage				

3.2 Self-consumption Measures

PV self-consumption	1	Right to self-consume	Yes
	2	Revenues from self-consumed PV	Savings on the electricity bill
	3	Charges to finance Transmission & Distribution grids	No
Excess PV electricity	4	Revenues from excess PV electricity injected into the grid	In average, the remuneration was 0.105 CHF/kWh (Source VESE, www.vese.ch)
	5	Maximum timeframe for compensation of fluxes	15min
	6	Geographical compensation	No
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	Few utilities changed their tariffs for prosumers (power metering)
	10	Regulations on enablers of self-consumption (storage, DSM…)	There are recommendations from the Swiss association of utilities, re: metering schemes for PV & battery storage. The solar association Swissolar has its own recommendation which differs from the one mentioned above. DSM is standard for large consumers to avoid power peaks but can be used for self-consumption optimization, as well. For residential self-consumption there are some regulations and provisional schemes on how to handle this.
	11	PV system size limitations	There is no limitation in system size.
	12	Electricity system limitations	No

	13	Additional features	No

3.3 Collective Self-consumption, Community Solar and Similar Measures

Until 2017, collective self-consumption is possible in Switzerland as long as all the consumers are in the same building; respectively, within the same perimeter of ground (same land owner). There are some restrictions with metering but more or less the system works quite well.
With the new legislation adopted in May 2017, collective self-consumption shall become much easier and also with possibilities of providing self-consumption services also to neighbouring houses. Details will be announced in November 2017.

3.4 Tenders, Auctions & Similar Schemes

There are no tendering schemes in Switzerland.

3.5 Financing and Cost of Support Measures

The federal support scheme is financed by a contribution paid by electricity consumers on a per kWh base.
Only very large consumers are exempted from this levy.
In 2016, the levy was 0.013 CHF/kWh. This will be increased to 0.015 CHF/kWh for 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.
These voluntary building standards help 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).

4.1 Highlights of R&D

Excerpt from the IEA PVPS Annual Report 2016, by Stefan Nowak, Switzerland, IEA PVPS Chairman:

"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.
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 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. 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)."

4.2 Public Budgets for Market Stimulation, Demonstration / Field Test Programmes and R&D

Table 14: Public Budgets for R&D, Demonstration/Field Test Programmes and Market Incentives

	R & D	Demo/Field Test
National/Federal	n/a	n/a
State/Regional	n/a	n/a
Total		

5 INDUSTRY

5.1 Production of Feedstocks, Ingots and Wafers (Crystalline Silicon Industry)

There is no feed stock, ingots and wafers production in Switzerland.

5.2 Production of Photovoltaic Cells and Modules (including TF and CPV)

Total PV cell and module manufacture together with production capacity information is summarised in Table 15 below.

Table 15: Production and Production Capacity Information for 2016

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					
1 Sunage	sc-Si, mc-Si	0	9.5	0	n/a
2 Megasol	sc-Si, mc-Si	0	19.5	0	n/a
3 Meyer Burger	sc-Si, mc-Si	*0*	10	0	n/a
All others	sc-Si, mc-Si	*0*	*1*	*0*	*n/a*
Total	sc-Si, mc-Si	*0*	*Approx. 40*	*0*	*n/a*
Thin film Manufacturers					
1 Flisom	CIGS		n/a		Pilot line 15MW
TOTALS			**Approx. 40**		**n/a**

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

b) About 20 MW of the manufactured modules in Switzerland were exported (Mainly Sunage and Megasol).

c) Swiss manufacturers are specialized in BIPV products. This is supported by enhanced support schemes for BIPV installations. Besides this, there is also a pilot production of hybrid collectors (PV and solar thermal).

5.3 Manufacturers and Suppliers of Other Components

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

Inverters:
Studer electronics manufactures inverters for stand-alone and storage solutions.

Junction Boxes/Connectors:
Multi Contact AG is the leading manufacturer of junction boxes, cables and connectors.
They claim to have a market share of 50% with module connectors.

Cables:
Huber & Suhner has been offering a variety of dedicated PV cables for more than 20 years.

Supporting Structures:
Montavent offers mounting systems for profiled metal and corrugated roofs.
ALUSTAND has mounting structures for tilted and flat roofs.

Storage Batteries:
Leclanché develops and produces energy storage systems with large format lithium-ion cells, amongst other products.

6 PV IN THE ECONOMY

6.1 Labour Places

There are different sectors where labour places can be counted as PV-related.
A growing sector due to more than 50 000 installed PV systems can be observed on the utility side (more systems getting connected year by year) and in the maintenance sector; especially in cleaning modules in order to increase the output.

Table 16: Estimated PV-related Labour Places in 2016

Research and development (not including companies)	200
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	4 000*
Distributors of PV products	
System and installation companies	
Electricity utility businesses and government	300 (estimated)
Other including maintenance	1 000*
Total	5 500

*Based on the value of PV business in table 17

6.2 Business Value

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

Table 17: Value of PV Business

Sub-market	**Capacity Installed *in 2016* (MW)**	**Price per W** *(from table 7)*	**Value (Mio CHF)**	**Total Mio CHF**
Off-grid domestic and non-domestic	*0.2*	*5*	*1*	
Grid-connected distributed & centralized	**270**	**1.95**	*526*	
				527
Export of PV products				*400*
Change in stocks held				*0*
Import of PV products				*175*
Value of PV business				***752***

7 INTEREST FROM ELECTRICITY STAKEHOLDERS

7.1 Structure of the Electricity System

About 700 utilities operate in Switzerland. Most of them serve only one village or town (DSO = Distribution System Operators) and are mostly publicly owned or organized as a cooperative of the customers.
For PV, there is only one regulation on the national level which defines how much a utility has to pay for solar electricity as a minimum. Many utilities pay a premium which is normally below the national FiT but still helps their local producer to cover at least a part of the production costs.
Grid connection is allowed by law but each of the DSO may have its own specific technical regulations (which do not vary much among them).

7.2 Interest from Electricity Utility Businesses

The PV experts who are organized within Swissolar, the professional association, are now established partners within the “grid stakeholders” in terms of standards and codes. Thus, PV experts take part in working groups organized by the Swiss Utility Association VSE in order to revise recommendations for grid connections, helping to overcome some issues with inverters, etc.
Some of the 700+ Swiss utilities are building up new business units by installing PV systems themselves. The market share of the utilities, mainly DSOs, is estimated to be more than 30% and is still growing.

7.3 Interest from Municipalities and Local Governments

More and more municipalities are becoming aware of their own huge potential for solar energy on roof tops.
Thus in the last couple of years, a new wave of PV installations on public buildings is developing all over Switzerland.

8 HIGHLIGHTS AND PROSPECTS

On September 30. 2016 the Swiss Parliament adopted the Energy Strategy 2050 with set targets for PV until 2050 (about 20% share).
Due to the public referendum, the Swiss had to vote for this on May 21st 2017; and they said yes!
The energy strategy will show and define the way for the next decade not only for PV but for all the other renewable sources since the Swiss voters also agreed to put a ban on any new nuclear power plants. Thus, there is a need to substitute more than one third of the Swiss electricity consumption generated by nuclear power plants with new, renewable and clean power generation. PV is foreseen to be the main share of this.