Sun at School - SONNEonline
Results of Two Photovoltaic School Promotions

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ABSTRACT: The purpose of this work is the presentation of two different photovoltaic promotion programs concerning schools created by two German utilities. Operation Results have been achieved for several hundred grid-connected PV systems in schools and evaluation has been carried out by the "*Fraunhofer Institut für Solare Energiesysteme ISE*" and the "*Solarenergieförderverein Bayern (Bavarian Association for the Promotion of Solar Energy = SeV)*" for both programmes for several years. The following contribution reports about the programs, their operation results and the internet presentation.

Keywords: Education and Training-1: National Programme-2: Grid-Connected-3

1. INTRODUCTION

1.1 Photovoltaic Promotions

Up to the year 2000 there were in Germany -among others- the photovoltaic promotion programs *Sun at school* sponsored by the utility *Bayernwerk*. and *SONNEonline* supported by *PreussenElektra*.

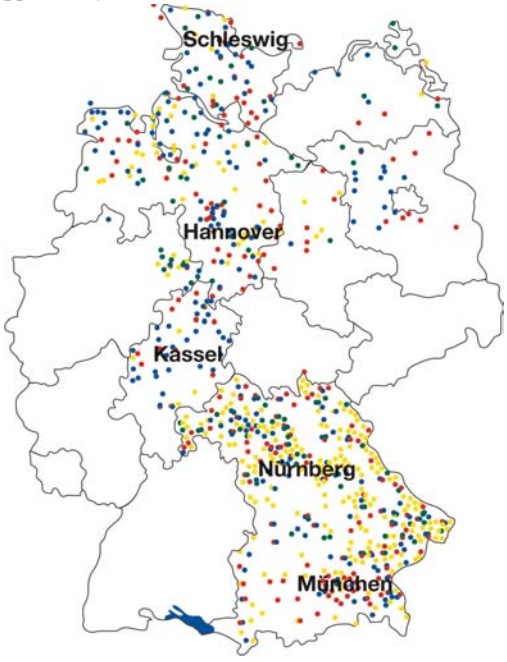

Figure 1: The schools are spread all over Germany

As in the year 2000 the two utilities merged together for *E.ON-Energy*, the two promotion programs have merged, too. Now an area reaching from the north to the south of Germany is covered, see **Fig. 1**.

It is the aim of this contribution:

- to describe both programs and their merger
- to present an outline of the operation data for several years
- to illustrate the internet presentation

The results are covering the years 1999 – 2001.

It is well known, that there are similar programs in Germany and other countries. As an example [1] with 21 and [2] with 100 grid connected PV Systems in schools shall be mentioned.

1.2 Irradiation Data

Irradiation is the most important input quantity for a photovoltaic system. In the area of *Sun at School* its Intensity may be characterized by the values of two cities. In Munich in 2001 1162 kWh/m² have been harvested, in Nürnberg 1089 kWh/m².

The area of *SONNEonline* shows lower irradiation, again demonstrated by values of three cities in 2001: In Kassel 1000 kWh/m², in Hannover 1001 kWh/m² and in the very north, in Schleswig, only 962 kWh/m².

Roughly estimated, the irradiation mean value in the area of SONNEonline lies more than 10 % lower than the one in the area of *Sun at School*.

2. DISCRIPTION OF BOTH PROGRAMS

2.1 Sun at School

Within the project *Sun at School*, initiated and promoted by *E.ON-Energie* - formerly *Bayernwerk* - it was possible to combine innovative technology with an innovative idea and to take an important step towards spreading photovoltaic technology.

Pupils and teachers throughout Bavaria were directly confronted with modern photovoltaic technology. For many young people *Sun at School* was an opportunity to go into the subject of energy in greater detail.

Between 1994 and 1997, 544 schools received a highly subsidised PV construction kit for a grid-connected photovoltaic system with an electrical output of over 1 kW.

Teachers and pupils together, with the support of regional and local power supply utilities, were responsible for assembling the system. So they received a good idea about the practical side of this new technique.

Figure 2: Sun at School - 1.1 kW PV system of a grammar school in Passau in the south of Germany

The photo above (**Fig. 2**) shows an example PV system. At the Adalbert-Stifter Grammar School in Passau the PV-plant is closely integrated into the teaching process.

Two sizes of PV generators were applied, consisting of 20 modules in each case. The rated output power values are 1,06 kW/1,10 kW with nominal module efficiencies of 12,4 %/12,9 %. The appropriate inverter show a nominal power of 1,1 kW with an efficiency of 92%.

The monitoring and evaluation work has been carried out by the *Solar Lab of Munich University of Applied Sciences* in order of the *Solarenergieförderverein Bayern = SeV (Bavarian Association for the Promotion of Solar Energy)* in conjunction with *E.ON-Energy*. The yearly created operation report has been sent to the schools. It is also available for download on the internet.

2.2 SONNEonline

SONNEonline was a PV-program mainly of the former utility *PreussenElektra* – now *E.ON-Energy*. In 1996 about 400 schools in the area of Northern Germany were provided with grid-connected PV Systems of approximately 1-kW PV power.

SONNEonline was based on a profound pedagogical concept which aims to introduce PV-technology to a clientèle of pupils and teachers, which is expected to multiply in the years to come. One of the most innovative aspects of this project is the combination of PV-technology with modern information-technology, i.e. the Internet. In addition to the PV systems, the schools received a Personal Computer and Internet access, allowing a detailed exchange of their system results and general experience with photovoltaics. **Figure 3** shows an example system.

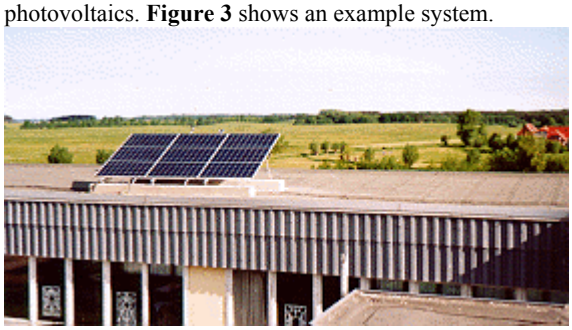

Figure 3: *SONNEonline* - 1.0 kW PV system of a grammar school in Samtens in the north of Germany

The PV generator shows nominal values for power of 1,08 kW_P and for efficiency of 12,1 %, the inverter of 0,85 kW and 93%.

In addition, *SONNEonline* contained twelve installations of intensively monitored systems in comparison. Thus, for SONNEonline in following it will be distinguished between the Standard-PV systems, for which only the yields are available, and the intensively monitored systems, for which further data such as irradiation are available.

The systems were monitored by the "*Fraunhofer-Institut für Solare Energiesysteme ISE*".

2.3 Merger

In the year 2002, the programs merged. Now the *Bavarian Association for the Promotion of Solar Energy* is responsible for monitoring and evaluation work. In future only one report which will be available for download on the internet.

The former *Sun at School* also obtained two intensively monitored systems, but the whole number of this systems was reduced from twelve to seven.

The new name for both programs together is now *Sun at School*. It is planned to continue monitoring and evaluation of all systems up to the year 2006.

3. OPERATION RESULTS

3.1 Receiving Operation Data in both Programs

With such a large number of PV systems it is the problem, to get the operation data available for post processing.

It was agreed for *Sun at School* with the schools that annual measurement protocol sheets would be submitted, centrally evaluated in an operation report and made available to the schools again for comparison with the other plants. Normally, by the beginning of each year the schools received measurement protocols with the request to send it back as soon as possible filled out with the monthly yields. There is now also the possibility of using the Internet for data transfer.

It must be mentioned, that the operation data received were faulty in some cases. Often unrealistic values were obtained because of an incorrect transfer of the data on the display to the sheet, and the operation data were not noticed for each month.

For *SONNEonline*, from the beginning of the promotion the operation data were sent monthly to the Fraunhofer ISE by the application of the Internet. For this purpose the schools had to apply a given password. Fraunhofer ISE evaluated the data, the report created could be obtained by download through the Internet.

Table 1 indicates that in both programs on the average about 50 % of all schools took part on the evaluation. Due to the experience the participation depends on how fast schools get a response on the operation data they send for evaluation.

Table 1: Number of schools which provided data – in the second row "1" indicates the absolute number of school providing data, "2" the appropriate percentage

Year	Sun at School		SONNEonline	
	1	2	1	2
2001	304	58%	170	43%
2000	290	62%	279	71%
1999	228	49%	164	42%

3.2 *Sun at School*

3.2.1 Final Yield

The output energy of the PV systems in operation in the years 1998 - 2001 reach from values of far below 500 to a high 1179 kWh/kW_{Peak}.

Figure 4 illustrates the distribution of the yields in the years 1998 - 2001 depending on "classes of yields" for *Sun at School*. A maximum can be detected at 700 - 800 kWh/kW_{Peak}, the discrete values of each "class" differ in the various years.

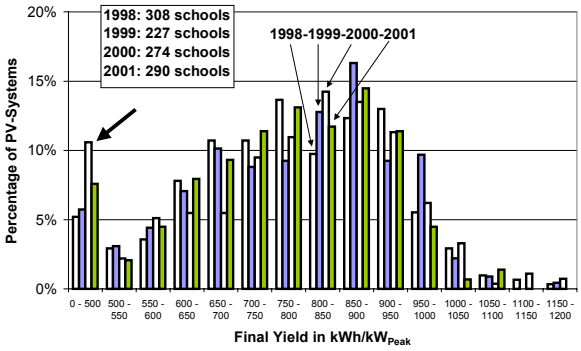

Figure 4: *Sun at School* – Distribution of final yields in 1998 - 2001

3.2.2 Malfunctions

The low yields in the class below 500 kWh/kW_{Peak} – marked with an arrow in Fig. 4 - were subject of a special consideration. The high percentage – especially in 2000 - in this class caused the *Bavarian Association for the Promotion of Solar Energy* to sent out engineers to find the reasons for the low yield and to remove them.

The main reasons found were:

- The PV system was unnoticedly switched off due to school renovation
- The electric meter was shifted
- Shadow by trees
- The memory of the inverter was disturbed by line transients
- Pupils switched off the inverter for a longer time

Considering all the PV systems evaluated, **Table 2** gives an idea of the main reasons for a decreased yield. Most of the trouble with the PV systems is coming from inverter failure.

Table 2: Reasons for decreased yield

Reasons for Malfunction	Range of Percentage
Structural measures e.g. building reorganization	2 - 10 %
Decrease in energy-production by ice or snow on PV-generator	1 - 10 %
Inverter failure	> 10 %
Other	2 - 4 %

3.2.3 Performance Ratio

As for none of the systems any irradiation measurement is available, it is not senseless to determine the Performance Ratio. The application of irradiation values measured only a few kilometres nearby was leading to unacceptable values.

3.3 *SONNEonline* – Standard Systems

3.3.1 Final Yield

Within the four years 1998 - 2001 values from below 500 up to a maximum of 1019 kWh/kW_{Peak} have been obtained.

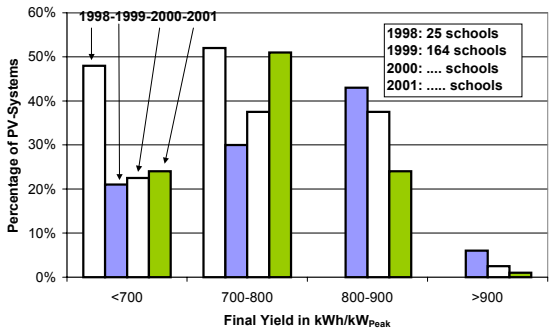

Figure 5: SONNEonline – Distribution of yields in 1998 – 2001

The diagram in **Figure 5** shows – analogously to Fig. 4 - the distribution of the yields in the year 2001 depending on "classes of yields" for SONNEonline. For 1999 – 2001 a maximum can be detected at 700 - 800 kWh/kW_{Peak}. The high yields in the range below 700 kWh/kW_{Peak} are well-founded in the fact, that only a comparatively small number of schools (25) took part in 1998.

3.4 Comparison

For both programs, results may be compared using **Figure 6**. This diagram illustrates for each class of final yield (<700 kWh/kW_{Peak}, 700 - 800 kWh/kW_{Peak} etc) the percentage of schools in this class for both programmes. For a clear presentation the mean values of *Sun at School* ans *SONNEonline* in the years 1999, 2000 and 2001 have been applied. The results of 1998 have not been taken into account, because the 1198 value of SONNEonline is extraordinary high, as mentioned above.

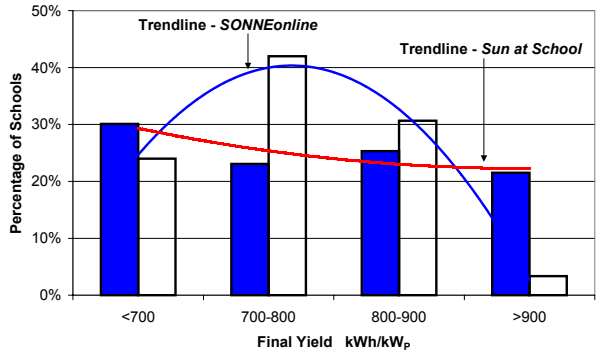

Figure 6: *Sun at School* and *SONNEonline* – Distribution of yields in 1999 – 2001

In this three years more than 40 % of the schools within *SONNEonline* obtained final yields between 700 and 800 kWh/kW_{Peak} , but more than 20 % of the *Sun at School* schools reached final yields greater than 900 kWh/kW_{Peak}.

It is indicated by the trendlines, that there is a greater number of schools in the "class" over 900 kWh/kW_{Peak} for Sun at School. The main reason is simple. In the south of Germany the irradiation values are higher.

3.4 Intensively Monitored Systems

3.4.1 Overview

As mentioned, *SONNEonline* contained twelve installations of intensively monitored systems, where the values of irradiation in the horizontal and the module plane, the AC and DC-power have been continuously (e.g. 5-minutes-mean-values) measured. Thus statements about Performance-Ratios and efficiencies are possible.

3.4.2 Characterizing Operation Data

Table 3 shows – for three years - characterizing operation data for the system with the best Performance Ratio PR in 2001 (Cloppenburg), for the system with the best Final Yield Y_F (Samtens) in 2001, and the mean values for all considered 12 installations.

Table 3: Nominal Power, Irradiation, Efficiencies, Performance Ratio and Final Yield for the Systems with best Performance Ratio and Final Yield best and mean value

2001

Location	P_{nom} kW	E_{Hor} kWh/m²	E_{Mod} kWh/m²	$\eta_{PV\text{-}Gen}$ %	η_{Con} %	PR %	Y_F kWh/kW$_{Peak}$
Cloppenburg	1,08	767	878	10,9	92,9	77,9	683
Samtens	1,08	937	1129	11,1	89,2	77,0	969
Mean		807	959	9,9	89,4	71,1	695

2000

Location	P_{nom} kW	E_{Hor} kWh/m²	E_{Mod} kWh/m²	$\eta_{PV\text{-}Gen}$ %	η_{Con} %	PR %	Y_F kWh/kW$_{Peak}$
Cloppenburg	1,08	759	877	10,8	92,2	77,2	677
Samtens	1,08	970	1193	11,2	89,5	77,4	923
Mean		830	1000	10,2	89,4	72,2	723

1999

Location	P_{nom} kW	E_{Hor} kWh/m²	E_{Mod} kWh/m²	$\eta_{PV\text{-}Gen}$ %	η_{Con} %	PR %	Y_F kWh/kW$_{Peak}$
Cloppenburg	1,08	769	886	11,0	91,7	78,5	695
Samtens	1,08	1031	1256	11,1	89,7	77,1	968
Mean		880	1050	10,2	89,8	73,5	772

Also, it indicates the behaviour of the irradiation in the horizontal and the module plane E_{hor} and E_{Mod}, the efficiencies of PV-Generator and Converter $\eta P_{V\text{-}Gen}$ and η_{Con}, Performance Ratio PR and Final Yield Y_F. It can clearly be seen, that all the values remain on the same level, no degradation can be found out. It can also be stated, that the interest and the maintenance given to the PV system by teachers and pupils are very important. The schools with high interest show good performance over the years.

4. INTERNET PRESENTATION

Both programs are available as Internet presentation with lots of information. One of the most important options is, that the actual operation values the intensively monitored systems can be observed, as illustrated **in Figure 7**. Please visit us: http://www.sev-bayern.de/

There was an enormous interest getting information by the application of the Internet. **Figure 8** illustrates the monthly accesses for SONNEonline, a maximum value of 25 000 proofs the acceptance of the program.

5. CONCLUSIONS

More than 900 schools in an area reaching from the north to the south of Germany received 1-kW respectively 1,1 kW PV systems. About 50 % of them – we think it is a good value - provided operation data for evaluation.

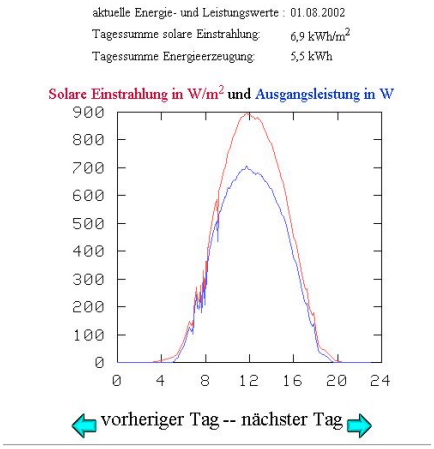

Figure 7: SONNEonline – actual irradiation and output power of the 1.1 kW PV system of a grammar school in Samtens in the north of Germany – to receive via Internet

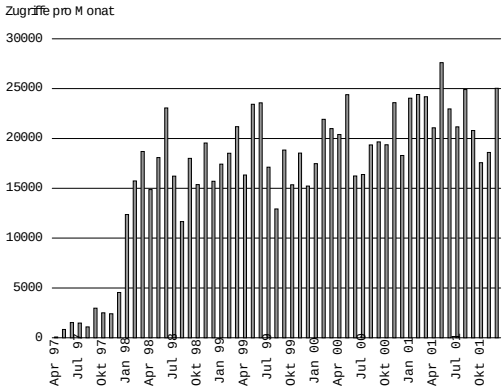

Figure 8: SONNEonline – number of monthly accesses

The PV systems show a good performance. Most of the trouble is coming from inverter failure. Structural measures, such as building reorganisation, often have an influence on the availability.

The final yields obtained lie in a wide range from below 500 kWh/kW$_{Peak}$ to over 1000 kWh/kW$_{Peak}$. Various reasons have been detected for the differences. For the intensively monitored systems, the Performance Ratios are higher than 70 %

Lots of information and as well daily characteristic curves are available via Internet, which is very well applied.

Supposing, that per year and school about 100 pupils get in touch with their PV system, within 10 years and nearly 1000 schools about 1 million young people will have received an idea of this innovative technology.

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