MONITORING
SUN AT SCHOOL
SEVERAL 100 PV SYSTEMS FOR NEARLY 20 YEARS

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INTRODUCTION

The first photovoltaic promotion programs for schools in Germany were launched from 1994 onwards. Two of them were **Sun at School** in Bavaria sponsored by the utility Bayernwerk and **SONNEonline** by PreussenElektra. As in the year 2000 the two utilities merged for E.ON, the two promotion programs have merged, too. The area now covered by the program **Sun at School** reaches from the North to the South of Germany, see Fig. 1.

At the beginning of both programs there were 944 participating schools, now there are 742 schools taking part. The PV systems are integrated in the teaching process, thus e.g. measurement data are being analyzed, the technology of the PV systems is discussed, etc.

During now approx. 20 years up to 2 million pupils, have come into touch with PV systems by **Sun at School.**

The program is being monitored since the merger of both programs in the year 2000 by the Solarenergieförderverein Bayern (Bavarian Association for the Promotion of Solar Energy).

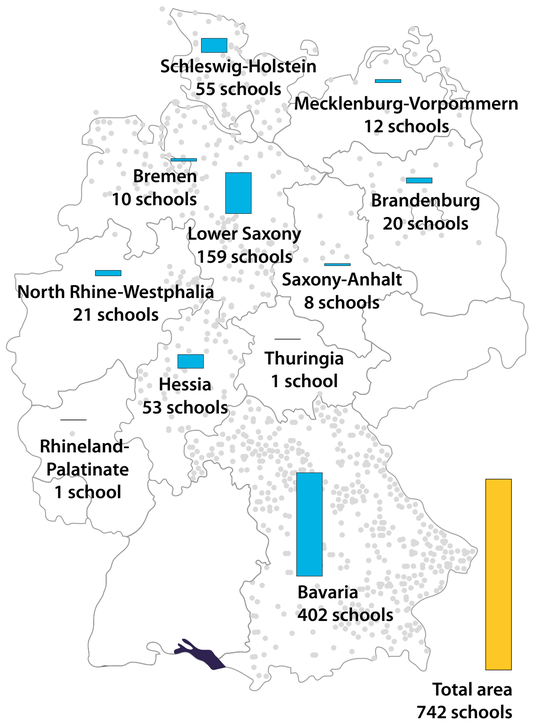


Fig. 1: Many schools with PV systems **Sun at School** in various Federal States as in February 2014

Fig. 2: PV system of nominal power 1.1 kW (20 x Siemens M55) with inverter Siemens SPN 1000 of a grammar school in Coburg in the south of Germany

Fig. 3: SONNEonline PV system (9 x Kyocera KC120-1, inverter Sunny Boy SWR 850) of a grammar school in Braunschweig in the north of Germany

Sun at School

Between 1994 and 1997, 544 schools in Bavaria received a PV construction kit for a grid-connected photovoltaic system with an electrical output of approx. 1 kW. Teachers and pupils together, with the support of regional and local power supply utilities, were responsible for assembling the system. Therefore, they received a good idea about the practical side of this new technique. Fig. 2 illustrates a sample system.

Two sizes of PV generators were installed, consisting of 20 modules Siemens M55 or Siemens M53 in each case. The nominal power values of all modules are 1.06 kW resp. 1.10 kW. The appropriate inverter Siemens SPN 1000 shows a nominal power of 1 kW.

SONNEonline

In the year 1996 about 400 schools in the Northern Federal States of Germany were provided with grid-connected PV Systems of approximately 1 kW PV power. Fig. 3 shows an example system. The PV generator consists of 9 modules with nominal power 120 W each and an inverter Sunny Boy SWR 850.

TECHNICAL DATA OF PV SYSTEMS

MONITORING

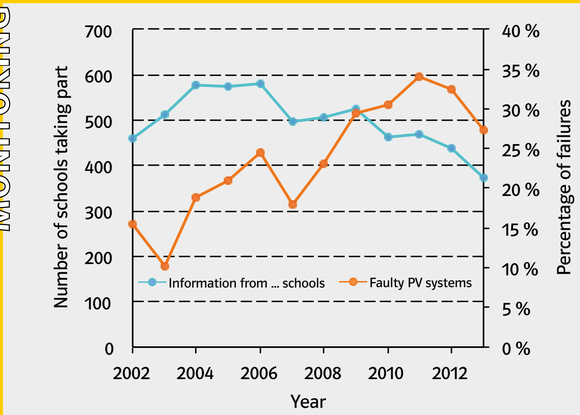


Fig. 4: Participation of the schools from 2002 to 2013 and percentage of faulty systems

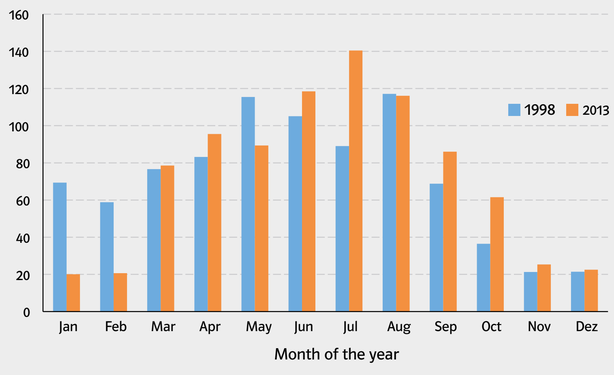


Fig. 5: Monthly final yield of a school in Northern Bavaria in 1998 (863 kWh/kW) and in 2013 (875 kWh/kW)

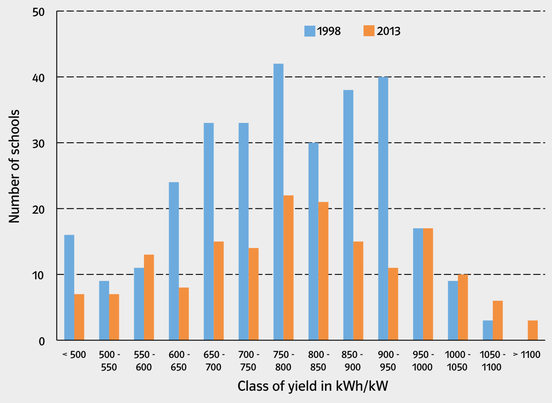


Fig. 6: Distribution of the yields for Bavaria in 1998 and 2013

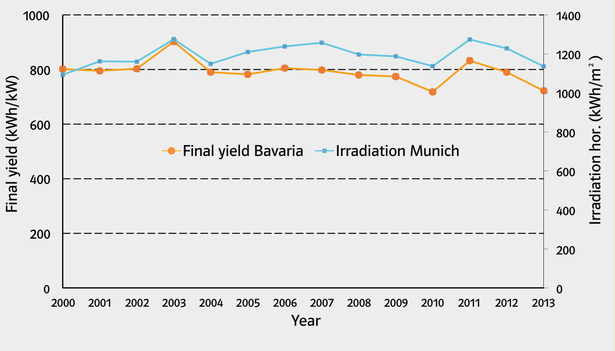


Fig. 7: Long-term yield and irradation for Bavaria from 2000 to 2013

Operation data provided by the schools

The schools were asked to write down the monthly yields and send them for evaluation. Additionally information about failures, etc. was requested. The percentage of schools that have sent monthly yields back, was on a high level. Fig. 4 indicates the number of schools which have sent back information.

Central Coordinator

It has become clear, that for a successful operation monitoring, supervision, assistance of the schools and appropriate reports would be necessary. Thus, a central coordinator has been installed to assist the schools. The tasks were: Collect operation data, gather information about malfunction of the PV system, organize the repair of defective systems, generate a report for the schools

Final yield

All the schools received the report about the behavior of all the PV systems and an individual diagram representing the monthly yields of its PV system. Fig. 5 shows the diagram of a school.

Each school receives the distribution of all yields in "classes" of the width 50 kWh/kW. Thus, the schools get an idea of their yield within all schools. As Fig. 6 shows, the number of schools with PV systems without failures has gone down. However, the mean yield and the distribution over the months remain the same.

There is a good correlation beween the long term yield and the irradiation on a horizontal plane, see Fig. 7. This effect is illustrated for Bavaria in the years 2000 to 2013. If other areas are considered, the same effect would occur.

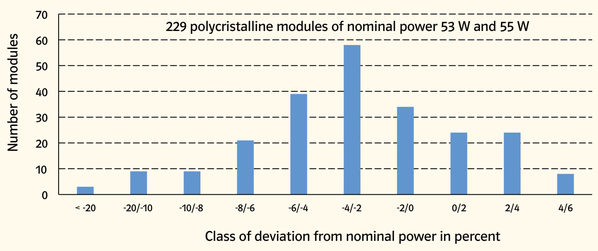
Low Yields/Failures

Low yields are coming from shadowing and from failures of components of the PV systems, mainly the inverter. Financial aid was given to the schools to repair or to replace the inverter.
For none of the PV systems any irradiation measurement is available. Thus, it is senseless to determine the Performance Ratio.

DEGRADATION

Measurements in 2005/2006

Investigations and measurements of the nominal power of some modules have been carried out in 2005 and 2006. It has been concluded, that after long years of operation no module has reached the nominal power. As no value of the initial power at the installation time was available, this effect can come from degradation, but as well from the fact, that the original output power was considerably smaller than the value of the nominal power on the label.



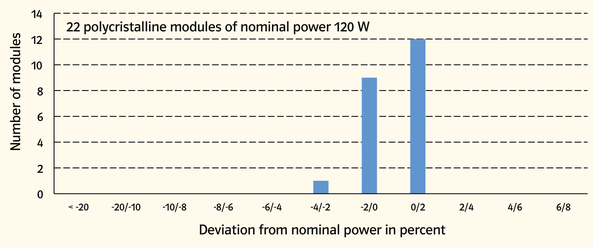


Fig. 8: Measurements of the the nominal power of 251 modules **Sun at School** in 2012

Measurements in 2012

To make realistic statements about the size of the degradation, the nominal power of more than 200 modules has been measured. Fig. 8 illustrates the results. There is a deviation to the nominal power on the nameplate. Most of the 229 modules of nominal power 55 W and 53 W show a difference between - 2 % and - 4 %. The smaller number of modules of 120 W indicates principally the same behaviour.

ON-SITE-INSPECTION IN 2014

To obtain information on long-term behavior of the PV systems, measurements have been commissioned on the **Sun at School** systems in Forchheim (Initial operation 1995), Coburg (1995), Würzburg (1996), Bayreuth (1995), Braunschweig (1994) and Kassel (1994). The systems are in a generally good condition, but they are partially shaded. The wiring is usually – exception see Fig. 9 – properly done. Often the modules and boxes were dirty, see Fig. 10.

The results of the performance measurement with a mobile calibrated test center for photovoltaic modules are indicated in Fig. 11.

Electroluminescence Investigations

The number of microcracks of the 53 and 55 W modules lie – if the age is considered - in very good frame. However, the investigated modules of nominal power 120 W show an extremely high number of microcracks. This can lead to accelerated aging, the spread of hotspots to failure of individual modules. In addition, the modules of nominal power 53 and 55 W show partial delamination and detachments of the solder on the cell connectors.

Fig. 9: Earthing wire not properly mounted (Kassel)

Fig. 10: External pollution of the generator terminal box (Forchheim)

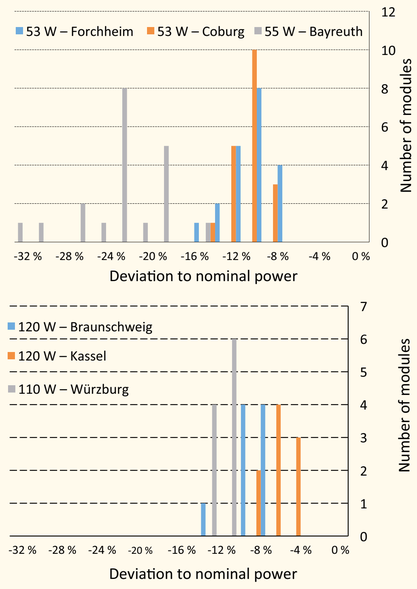


Fig. 11: The upper diagram indicates a strange behavior. The measured output power values of the modules in Coburg and Forchheim show the same deviation to the nominal power. However, the modules of 55 W have significantly greater differences to the nominal power. The lower diagram indicates a maximum difference of 14 % to the nominal power.

CONCLUSION

The long-term behavior of many small grid connected photovoltaic systems **Sun at School,** based on the monitoring data, show that the systems are – after a maximum of 20 years of operation – in a good technical condition. However, many problems occurred during the operation within the last 20 years. The investigation of six exemplary photovoltaic systems after nearly 20 years of operation shows a good technical condition. Also in the next years they can be safely operated further. Therefore, the SeV Bayern intends to continue **Sun at School** in the coming years. Thereby assisting the schools for the training of the pupils in the field of renewable energies continues!

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