basisEnergie 6

BINE Informationsdienst

Schools plug into the sun

Photovoltaic systems in schools help save energy and enhance classroom teaching. They shape a school's image and indicate that energy supply is a future-focused subject. Grants are available to schools wanting to install photovoltaic panels.

INTRODUCTION

Looking to the future, one of the most important social challenges is securing an environmentally sound and sustainable energy supply. This challenge calls for scientific research and technological innovation, which depends on the availability of experts like engineers, tradespeople and scientists. They all rely on cooperation from other specialists in areas like marketing, business and social science. Interest and motivation to enter into a technical profession is usually sparked at school, where the foundations are laid for later working life. Apart from communicating facts, schools are also responsible for awakening an interest in technology, motivating children and young people to assess risks and opportunities, and enabling them to gather basic practical experience.

Photovoltaic systems in schools are a good way of integrating renewable energy technologies into the school curriculum. Access to a system allows school children to deepen their theoretical knowledge, compare meter readings and calculate yields. Monitoring their own electricity consumption and comparing it with the amount of solar energy produced gives them a realistic idea of the 'value' of electricity and the level of effort and potential involved in photovoltaics. With an expected lifecycle of more than 20 years, photovoltaic systems can benefit many school generations. Schools often showcase their systems at school events and so provide the general public with an ideal opportunity to inform themselves about photovoltaics. Installation of a photovoltaic system often results in the school taking a critical look at its electricity and heating needs to enable energy-saving decisions on ventilation and heat supply. The subject of photovoltaics offers a wide range of opportunities for interdisciplinary work, e.g. communications, geography, and even German and art in designing public relations material. At project schools, the children are often so highly motivated that they make more use of energy-saving opportunities in their private lives as well. With its *Sonne in der Schule* (solar energy in schools) scheme, the Federal Ministry of Economics and Labour(BMWA) awards grants of up to € 3,000 for the installation of photovoltaic systems in schools. More than 300 schools had made use of these grants by April 2000. And there is an added benefit: each kilowatt hour fed into the local grid is remunerated in accordance with the Renewable Energy Act (EEG). For systems put into operation in 2000/2001, that means 45,7 €-Cent per kilowatt hour.

Fig. 1 *School children install a PV system [Wentzinger Schulen, Freiburg]*

KEYWORDS

--> Social challenges
--> Research
--> Solar energy in schools

SOLAR ENERGY IN SCHOOLS

The *Sonne in der Schule* scheme provides schools with grants of up to 3,000 € for photovoltaic systems with an output of at least 1 kW_p. At current prices, this means that the school or education authority pays between 5,000 € and 7,000 € for a 1 kW system. The schools are given free license in selecting the type of modules and components for their system. They are responsible for obtaining planning permission and for system operation, maintenance and safety. As part of a three-year scientific research project, schools agree to report monthly yields by taking the readings form their existing electricity meters. For teaching purposes, they receive an additional monitoring system free of charge. This comprises a sensor for solar input, a data collection system to store daily quantities for the parameters of solar energy collected, electricity generated, and electricity fed into the grid. It also contains software to chart the data. One funding requirement is that the system be connected to the local grid. **Figure 2** shows the distribution of annual yields for 1999. Figure 3 shows the top ten project schools.

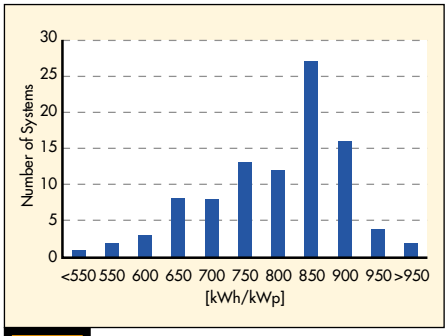

Fig. 2 *Distribution of annual yields in 1999*

School	Post Code	Location	Yield (kWh/kW_pa)	Module Type	Inverter
Wentzinger – Schulen **	79110	Freiburg	1,149	MSX 64 [1]	SWR 850 [6]
BBS Naturwissenschaften	67059	Ludwigshafen	956	M 55 [2]	SWR 850 [6]
Heidegymnasium	06909	Pretzsch	955	M 55 [2]	SWR 850 [6]
Kreisberufsschule	23758	Oldenburg	931	M 55 [2]	SPN 1000 [2]
Gewerb. und Hausw. Schulen	77694	Kehl	926	M 55 [2]	SPN 1000 [2]
Wentzinger-Schulen	79110	Freiburg	925	MSX 64 [1]	SWR 850 [6]
Berufliche Schulen Kreis Ostholstein	23701	Eutin	920	SF 115 [3]	SWR 850 [6]
Berufliches Schulzentrum	74321	Bietigheim-Bissingen	915	M 110 [2]	DMI 100 [7]
Hans-Thoma-Gymnasium	79540	Lörrach	914	I-110 [4]	SWR 850 [6]
St. Meinrad-Gymnasium	72108	Rottenburg	911	H 800A [5]	Fronius 2000-1
Nepomucenum	48653	Coesfeld	903	MSX110 [1]	SWR 850 [6]

** System includes concentrators; [1] Solarex; [2] Siemens; [3] Solarfabrik Freiburg; [4] Isofoton; [5] Helios; [6] SMA; [7] Dorfmüller

Fig. 3 *The top ten systems according to annual yield in 1999*

Installation of a photovoltaic system provides schools with a project that both requires and fosters a range of skills in children, teachers, parents, and school authorities. **Figure 4** shows a selection of these skills.

RESPONSIBILITIES

Organisation
- Project planning
- Lobbying (e.g. school authorities)
- Fundraising
- Public relations work

Hands-on
- Working under supervision
- Assisting with installation

Business Administration
- Butget yield
- Budget income
- Environmental impact assessment

Planning
- System design
- Site analysis
- Yield prognosis

Fig. 4 *Selected project requirements*

In recent years, many German energy providers and their regional partners, e.g. HEW, BEWAG, EVS, ESAG, Bayern Werke and PreussenElectra (SonneONLINE), have sponsored over 1,000 photovoltaic systems in schools in the regions they served. The SonneONLINE project, for example, provided schools with a standard 1.1 kW_p system along with internet access to enable communication between participating schools (see page 4 for further details).

ZENTRALE BEGRIFFE

--> Funding requirements
--> Data collection
--> Annual yields

EXPANDING SYSTEMS

The Wentzinger Schulen (a lower secondary and grammar school) in Freiburg used the occasion of their 25th anniversary in 1997 to start their solar energy project. A 1.15 kW_p system was installed at the initiative of two teachers. Children, parents and teachers jointly decided to continually expand the system. By the summer of 2000, the photovoltaic system had grown to 21 kW and was made up of components from various manufacturers. Part of the system (approx. 1.2 kW) is equipped with a V-trough concentrator to enhance the amount of light that hits the modules. At various times throughout the year, both the concentrator modules and the other modules are repositioned to line up with the shifting angle of the sun. According to experience gained at the Wentzinger Schulen, the concentrator system has an average 20 - 30 per cent more output than similar systems without a concentrator. Some 80 pupils of varying ages were involved in assembling and installing the system, and in presentation of the project online. The school did, however, commission a qualified electrician to inspect and connect the system to the public grid, as required by law.

The solar project is now a central focus of identification in the school. In 1997, the schools formed a non-profit organisation, Wentz-Solar e.V., to promote renewable energy technologies and energy-saving measures at the Wentzinger Schulen. The schools are also involved in Baden Württemberg's Klimafreundliche und energiesparende Schule scheme, which promotes climate protection and energy saving in schools. Energy savings amounted to 16,500 € in the 1998/99 school year, and 21,500 € in 1999/2000. The savings can be used to fund additional energy-saving measures and to expand the photovoltaic system (**Fig. 5**).

Fundaraising activities 1997	6,500 €
Donation from parents	2,500 €
Pupils Initiative: Sports and SolarEnergy Days	20,000 €
Wentz- Solar e.V. members` contributions	10,000 €
Energy saving	10,000 €
Various grants (including € 6,000 from the *Sonne in der Schule* project	20,000 €
Public loans	56,000 €
Electricity sold to local electricity authorities	1,000 €

Fig. 5 *Funding of the Wentzinger Schule system*

TECHNICAL AND VOCATIONAL TRAINING I

The photovoltaic system at the *Beruflichen Schule* (Technical and Vocational Education Training College) in Eutin, Kreis Ostholstein, was installed on a flat roof in October 1997 (**Fig. 6**). It cost a total of 17,000 €, of which 14,000 € was paid by the Landkreis (district authority) in its capacity as the education authority and 3,000 € by the *Sonne in der Schule* scheme. The system has worked fault-free since going into operation and has clocked up some 22,423 operating hours (as at September 2000) with an output of 5,146 kWh. The excellent yield achieved in Eutin shows that above average yields can be obtained in the northern Länder (states) of Schleswig-Holstein, Mecklenburg-West Pomerania and Lower Saxony. Up to now, the electricity generated has been fed into the school network, although the school authorities plan to connect the system to the public grid. Photovoltaics is part of the curriculum for trainee electricians and gas and water technicians at the TVET college, and also for the pupils in the nearby vocational grammar school. Production of solar-generated electricity has been integrated into a teaching unit on renewable energy sources. The photovoltaic system deepens theoretical knowledge, allowing pupils to follow the path of solar-generated electricity from the PV module to the grid. This includes analysis and graphical display of meter readings.

Fig. 6 *TEVT college in Eutin*

TECHNICAL AND VOCATIONAL TRAINING II

A 1.1 kW_p adjustable system was installed on a flat roof at the TVET School Centre in Bietigheim-Bissingen. The mechanical design work was done under teacher supervision by pupils participating in the 1 and 2-year courses. Records of the supporting construction include: 100 m aluminium channel, approx. 530 drill holes, 68 sawn angles and 34 filed slits. Apart from public funding, the school received donations from its *Förderverein* (friends of the school association) and the *Elektro-Innung* (Electricians' Guild), and used a portion of its annual budget.

Trainee electricians learn about the circuit diagram, the components and grid connection. Output data are collected on an ongoing basic and are graphically displayed. A range of photovoltaic island applications, like a weather station, have been developed as part of the normal course work. With the exception of one inverter defect, the system has been completely reliable and supplies electricity to the public grid (**Fig. 7**).

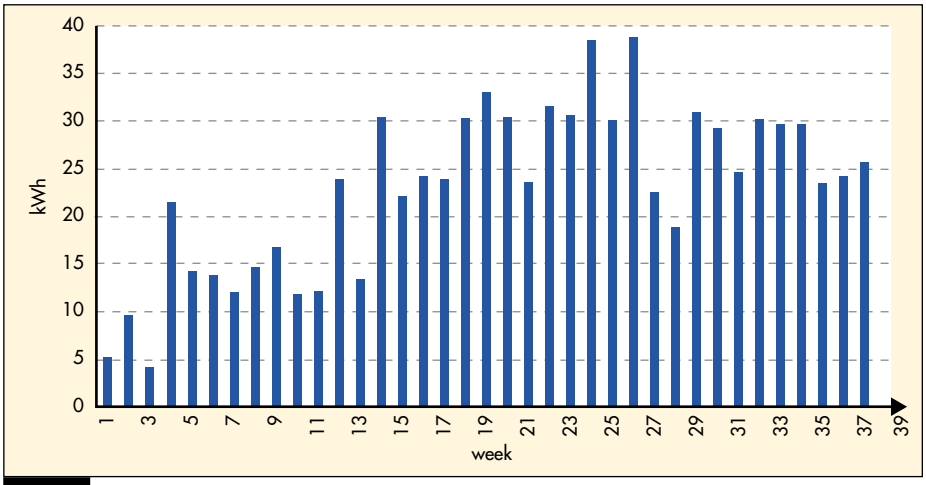

Fig. 7 *Weekly yields (in kWh/kWp) from the system at Bietigheim-Bissingen*

PHOTOVOLTAICS IN THE CLASSROOM

The 1.1 kWp system at the Nepomucenum Gymasium (grammar school) in Coesfeld went into operation in September 1998. Pupils in the 10th grade worked on assembling the supporting construction and the module as part of their science elective. Their efforts contributed approximately 1,000 E to the system's overall total cost of 8,500 E. The rest was put up by the town of Coesfeld and the Förderverein (friends of the school association), the actual owner of the system. **Figure 8** shows the monthly yields for 1999.

The solar electricity system is integrated into science lessons for the 9th and 10th grades. The lessons cover energy, energy generation, diodes, semiconductors, optimum positioning of the system, and system output. Experiments allow identification of the most efficient angle for the system and of average daily, monthly and annual yields. Pupils also learn how solar-generated electricity can be used to generate hydrogen for fuel cells.

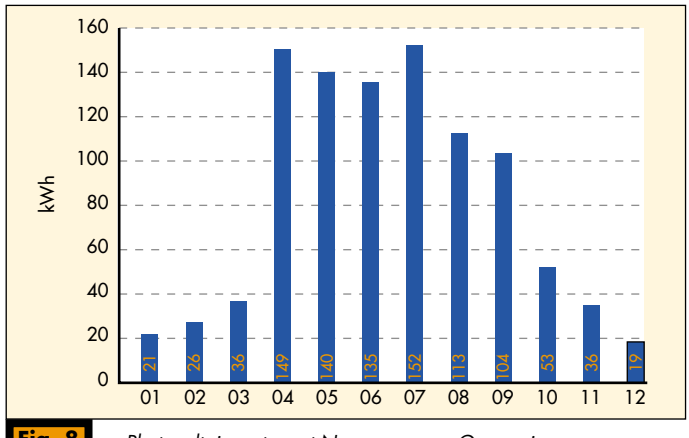

Fig. 8 *Photovoltaic system at Nepomucenum Gymnasium Monthly yields 1999 (kWh/KWp)*

FURTHER OPTIONS

School PV systems with a grid connection provide the perfect setting for integration of system construction, components and output into classroom teaching. The market also offers a range of experimental and teaching modules for more detailed experiments on the physical properties of photovoltaics. These contain basic experiments for use in both school and vocational education, instructions for independent learning for pupils and recommendations for teachers. A list of providers is available on the BINE web site (see below). **Figure 9** shows some of the more typical uses for integration into physics lessons.

School-owned PV systems not only offer a range of educational options. With the Renewable Energy Act (EEG), they provide system operators with an additional source of income.

Solar cell characteristic: measuring current and voltage relative to:
- Load (identifying peak output point)
- Light intensity
- Light wavelength
- Cell temperature

Light conditions, geometry
- Impact of angle on solar cell output
- Direct and diffuse light (covering components; shading)
- Concentrators (mirror and lens systems)

Interconnecting of solar cells
- Parallel circuit (current addition)
- Series circuit (voltage addition; shading effects)

Fig. 9 *Typical physics experiments*

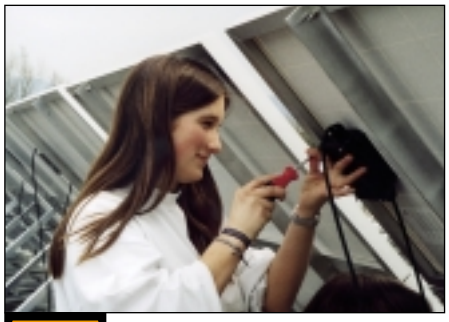

Fig. 10 *Assembling a photovoltaic system at the Wentzinger Schulen*

FURTHER INFORMATION

- Funding applications for the *Sonne in der Schule* project will be accepted up to the year 2006. Further information on the project is available for download on the BINE web site, where you can also find a list of learning modules and teaching materials on the subject of photovoltaics (in german).
- The Wentzinger Gymnasium has it's own web site at http://www.wentz.fr.schule-bw.de (click on Projekte)
- For more on the SONNEonline scheme, please visit http://SONNEonline.de
- A Energy Update brochure covering the scientific and technical aspects of photovoltaics is available free of charge from BINE (address below) or as a download from the web site.

LITERATURE

- Deutsche Gesellschaft für Umwelterziehung – Büro Schwerin (Eds.), Sonne in der Schule – Sonne macht Schule – Ein Projektergebnis in Text und Bild, Schwerin 2000
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