SOLAR ENERGY STUDIES AND EXTRAMURAL LEARNING

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Abstract Extramural learning refers to the educational process that takes place outside the walls of the school (or the university). Extramural learning that takes place in a science center is characterized by hands-on and interactivity. Interactive solar energy exhibits are particularly well suited for out-door science centers. The paper presents some solar energy hands-on exhibits and extramural activities that the author has initiated and participated in.

1. INTRODUCTION

During the 8th International Symposium on Renewable Energy Education in Orlando, Florida, 4-8 August 2002, I talked about the importance of public education and public understanding of renewable energy (Broman 2002). Then I cited the study Science and Scientists (SAS), which had asked 10 000 13-year old pupils in 21 countries: "What do you want to learn about?". The answer "New sources of energy - sun, wind" was among the 25% least popular answers, and it was much less popular among girls than among boys (Sjøberg 2000).

Why is it so? Pupils - and adults - are interested in scientific and technological subjects for a number of reasons: Economical reasons. Usefulness. Interesting, fun. Relevant (*ibid*.).

Renewable energy obviously does not meet these requirements!

A comment on relevance is the Johanna Argument:

Johanna, 9th grade: "It is a pity that I am not particularly interested in physics. I am for example interested in religion; you meet people all the time with different religions, so it is with you all the time - but physics is only with you two hours per week."

A question is obvious: How often do people meet renewable energy in their daily life?

If we want to do something about it, we must realize that

- Visibility of renewable energy is important
- The school is important
- Media are important
- Exhibitions, Science Centers and Science Parks could be used to meet people of all ages.

Extramural learning refers to the educational process that takes place outside the walls of the school (or the university). During many years, the author has been engaged in the kind of extramural learning that takes place in science centers, planetariums, and museums. Inspired by an exhibit at Exploratorium in San Francisco, where a heliostat on top of the building directed a beam of light down into the exhibition area, a *solar chimney* was constructed for The Futures' Museum in Borlänge (Broman and Back 1987). Since then, he has been engaged in the creation of interactive solar energy exhibits, several of which are described in this paper.

2. TRAVELING EXHIBITIONS

Extramural learning that takes place in a science center is characterized by hands-on and interactivity. Indoor exhibitions on solar energy may be hands-on if artificial light is utilized. SERC's traveling exhibition on solar energy was built in 1990 and subsequently shown in many places in Sweden (Broman and Gustafsson 1991). In the mid-1990ies it was sold to Grönhögens Energicentrum in southern Öland, where it is permanently on display. The photo below was taken there in 2002.

The exhibition presented both thermal and photovoltaic utilization of the sun's energy, using life-size paintings, actual artifacts, several cylindrical exhibits with models, hands-on experiments and a video, and a cinema where pictures of solar energy installations from all over the world were shown. There was a "solar cave" where visiting children could hide and draw their own crayon sun, which they could put on display at a big screen.

When used as a traveling exhibition, it was a custom to give teachers in-service training in how to use it with their pupils.

3. TEKNOLAND

Interactive solar energy exhibits are - for natural reasons! - particularly well suited for out-door science centers like Nehru Science Park in Bombay, India, Clore Garden of Science in Rehovot, Israel, and Teknoland in Falun, Sweden (Broman 2000).

Teknoland was open to the public at the Lugnet National Ski Stadium in Falun during the summer seasons 2000 and 2001. In the following, the interactive solar energy experiments of Teknoland will be described. Under each photo of an exhibit, the text of the exhibit label is given within a frame.

3.1 Yourself a sundial

A sundial, we thought, would be a "must" in an outdoor science center that included solar energy experiments. We wanted however the sundial to be interactive, and most designs that we hade seen were merely of the kind where you just watch the shadow of something cast onto some space with numbers showing the time of the day. It took a lot of thinking before the self-evident design struck us: The visitor moves until the shadow points towards a specific stone. Then the visitor's place determines the time of the day.

The design is best when the sun isn't too high in the sky, so the high latitude of Falun - 60° north - helped making even the noon shadow in mid-summer long enough. Due to the geometry of the changing path of the sun that changes the direction of the shadow as the months pass, and also because of the varying equation of time, the hour stones have to be adjusted every second week or so if you want the sundial to be really adequate.

Yourself a sundial

Stand straight on a grey stone so your shadow points towards the white stone. What time is it?

Since the sun's path over the sky changes a little from day to day, the places of the stones have to be changed from time to time. (Please don't move any stones yourself, let Teknoland's personnel do the adjustments!)

3.2 The solar heated chess board

The inspiration to this exhibition that illustrates how different surfaces absorbs sunlight differently is over two decades old, when the author paddled a canoe with a friend among stony outer islands in the Swedish west coast archipelago of Bohuslän. At one of the sunlit smooth cliffs, there was a big sign painted to help navigators. The sign consisted of a huge black rectangle surrounded by a wide white rim. When we stepped bare-foot from the red unpainted cliff onto the rim, it was very obvious that this was so much cooler, and when walking on the black-painted surface it was really hot.

The original Teknoland chessboard stones were made of plastic coated sheet steel formed to flat square shapes and filled with concrete. Several of the squares were however destroyed between the two seasons, so then we just painted ordinary concrete squares black and white, and it worked just as well. To make people walk on the chessboard we adopted an old game that takes a minute or two to play (instead of the long time it takes to finish a game of chess).

The solar heated chess board

Here you can walk around barefoot (and feel the difference between black and white squares!) and play *4 against 1*.

4 against 1: Two players, white and grey. You play only on white squares. Place the four white pieces along one edge. Place the gray piece at the opposite edge. The players take turns in moving a place to one adjacent white square. Gray player begins. White is only allowed to move ahead, never back. Gray wins if it manages to pass behind the white pieces. White wins if white shuts up gray so it cannot move. (No piece may jump over another piece.)

3.3 Solar thermal collectors

During Teknoland's second summer, we let visitors experience a number of solar artifacts, including a Czech solar water heater for camping use and an Indian solar box cooker. Another useful educational artifact was a previously described s(ch)olar collector (Broman and Gustafsson 1997). Experiments with the quasi-parabolic solar concentrator (Broman and Broman 1997) are described below.

3.4 Playhouse with solar electricity

Originally, we had wanted to run several experiments (like Elvis Ström's Electric Workshop) on solar electricity, but economical reasons stopped these ideas. In the part of Teknoland that we called *Toddlers' Teknoland*, we had equipped a playhouse with a PV-driven radio. It work (of course) very well when the sun was shining, but also quite well under a cloudy sky.

Playhouse with solar electricity
In the house there is a radio, which gets the required electricity from a solar panel on the roof. Cover the solar panel to quiet the radio.

Solar panels are also called PV panels (photovoltaic panels). Today, they are common where there is no electric grid. Then batteries are included in the system, which are charged when the sun shines and provide current also at night. The production cost of solar panels is steadily decreasing because the technology is being developed. Many predict that this environmentally benign technology soon will have a breakthrough also in the very large scale.

3.5 Solar concentrator

This very popular exhibition, built by *Orsa Sol* (phone +46 250 550 365), was for safety reasons only handled by an exhibition guide, not by the visitors themselves. It could be used either for baking pancakes or popping popcorns, which were subsequently served to the happy audience. The mirror was large enough to heat a pan hot enough even when the sky was hazy.

Solar concentrator
<u>Note: This exhibit is dangerous and may only be handled by Teknoland's staff!</u>
When the sun is visible, rays directly from it can be concentrated into a small area. A reflecting parabolic mirror creates almost a point. A near-parabolic mirror like this one produces a slightly wider spot. The concentrated light gives high temperature, so with a frying pan on that spot it is possible to fry pancakes or pop popcorn.

3.6 Solar collector surfaces

This experiment is a further development of one that was included in the traveling exhibition described above, and like the concentrator it was built by *Orsa Sol*. It includeed ten palm size pieces of Sunstrip® with different surfaces (metal, white or black paint, glazed with black paint, or selective surface). A bit surprising is the fact that a white-painted surface is cooler that a metallic (aluminum) surface; the reason is that while the surface doesn't absorb sunlight very well it is a good heat radiator.

Solar collector surfaces
Feel the different surface temperatures!
A black surface absorbs more sunlight than a white or a metallic. A surface turned towards the sun than one that is turned away from the sun. Glazing prevents radiation from the surface. A painted surface radiates heat easier than a metal surface and is therefore cooler.

4. AN ESES MASTER THESIS

John Ericsson, the rather well-known Swedish-American engineer and inventor, was born in 1803. The Swedish National Technical Museum in Stockholm has therefore built a semi-permanent exhibition which opened on 4 April 2003 called *Nedkalla solkraften!* (Call Down the Sun's Power). Ericsson was namely one of the early pioneers in converting concentrated sunlight to mechanical power using a heat engine of his own invention. For more on solar energy history including Ericsson's contributions, see Butti and Perlin (1980).

The exhibition includes much information on both solar thermal and photovoltaic technologies, also using some hands-on exhibits. Furthermore, in a classroom called Mekanikum, children can do experiments related to solar energy. These activities as well as the educational material used were developed by an ESES student, Ard Vlooswijk. Experiments considered were the s(ch)olar collector, the photovoltaic power car, the dye-sensitized solar cell, the human sundial, the game Solar Twister, and the pizza box heater. For more information on the experiments and the activities, see his master's thesis (Vlooswijk 2003).

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