Annual Comparison of Energy Yield
–
The Solyndra cylindrical CIGS Module, amorphous, and crystalline PV-Modules

Author: Qualified Electrical Engineer. (FH) Eberhard Zentgraf
at TEC Institute for Technical Innovation

Scientific team, involved in planning, set-up, measurements and analysis:
E. Zentgraf, S. Hock, A. Zentgraf

Table of contents

1. Preface:

During the second half of 2008 first reports about a novel PV-module were released. The North American company Solyndra (www.solyndra.com) developed a PV-module, made from tubular CIGS-films, see figure 1 and 2.

Beginning of 2009 the new modules were brought on the market. The manufacturer claims that the module orientation has no considerable impact on the energy yield. In addition, a white reflection film (simply, a white roofing film) ensures that reflected radiation reaches the underside of the cylinders and thus, heightens the energy yield. According to the manufacturer, these panels (external dimensions 71.65” x 42.52”) are suitable for structurally weak flat roofs without roof permeation.

Fig. 1: Cylindrical CIGS module by Solyndra

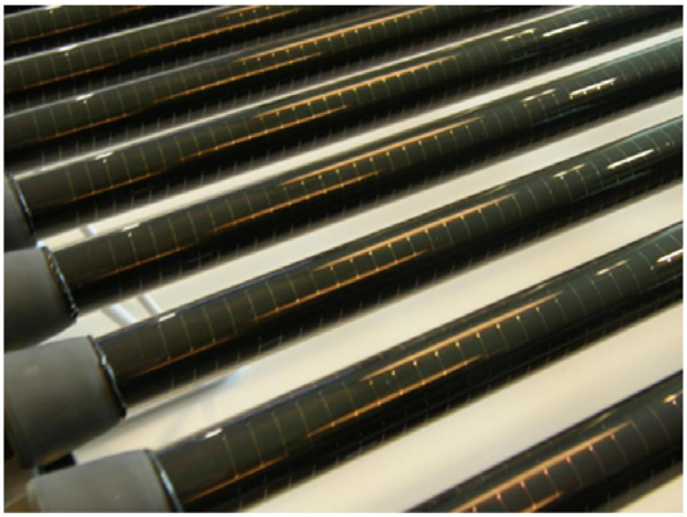

Fig. 2: Close-up of CIGS cylinders

The TEC Institute decided to take a closer look at this new technology. The module's demand of space as well as its energy yield in comparison with crystalline and amorphous PV-modules, were of particular interest to us. Tests were scheduled to run over a one-year period.

2. Set-up and Implementation:

Comparative test

Manufacturer:	Type:	Length [m]	Width [m]	Cell Type
Solyndra	SL-001-182 C	1,820	1,080	CIGS
Solartechnics	SN-GS-40D39D	1,245	0,635	a-Si
Aleo	S 16	1,660	0,830	poly
ANTARIS	ASM 175	1,580	0,808	mono

The mono- and polycrystalline modules, as well as a-Si-modules were mounted for testing without additional elevation support on a flat roof with an inclination of 7°. The CIGS-type's longitudinal axis (Solyndra) was aligned in a north-south direction. The white reflection film was laid out underneath (see fig. 3).

Fig. 3: The Solyndra-module on its reflection film

Characteristics of the testing period:

Testing began on 1st of March 2009 and ended February 28th 2010. The tests were carried out on the institute's own roof. Immediately after the measurements began, we discovered that the Solyndra module was shading its own reflection film in part or at times even completely, depending on the position of the sun, see fig. 4 and 5.

Fig. 4.: CIGS-cylinders cause partial shading of the reflector.

Fig. 5: CIGS-cylinders cause complete shading of the reflector.

3. Measuring Results:

Results from the measurement series:

From the measurements taken between 1st of March 2009 and the 28th of February 2010 ensued the annual energy yield of each module type, which can be seen in fig. 6. In order to be able to compare the different modules directly, the respective output is given in kWp, which is common practice in photovoltaics.

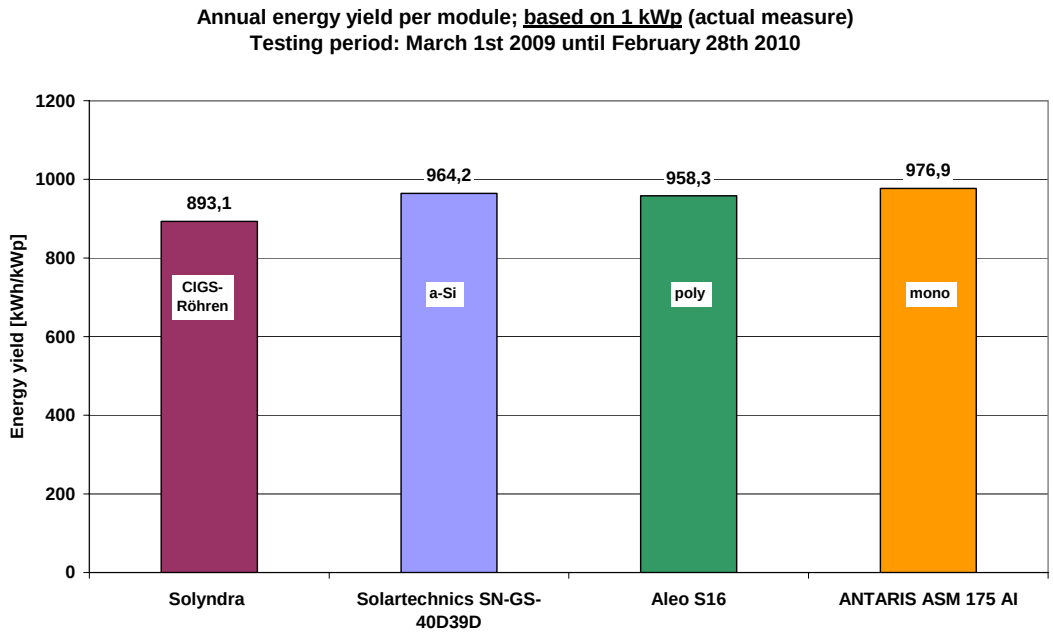

Fig. 6: annual energy yield [kWh/kWp]

Intermediate results:

While the three flat plate-modules (monocrystalline, polycrystalline and amorphous silicone) were having a neck-and-neck race (with the monocystalline module slightly in the lead), the cylindrical CIGS module showed considerably less annual output, based on kWp.

Monthly observations:

Fig. 7 shows how the monthly output spreads over the year.

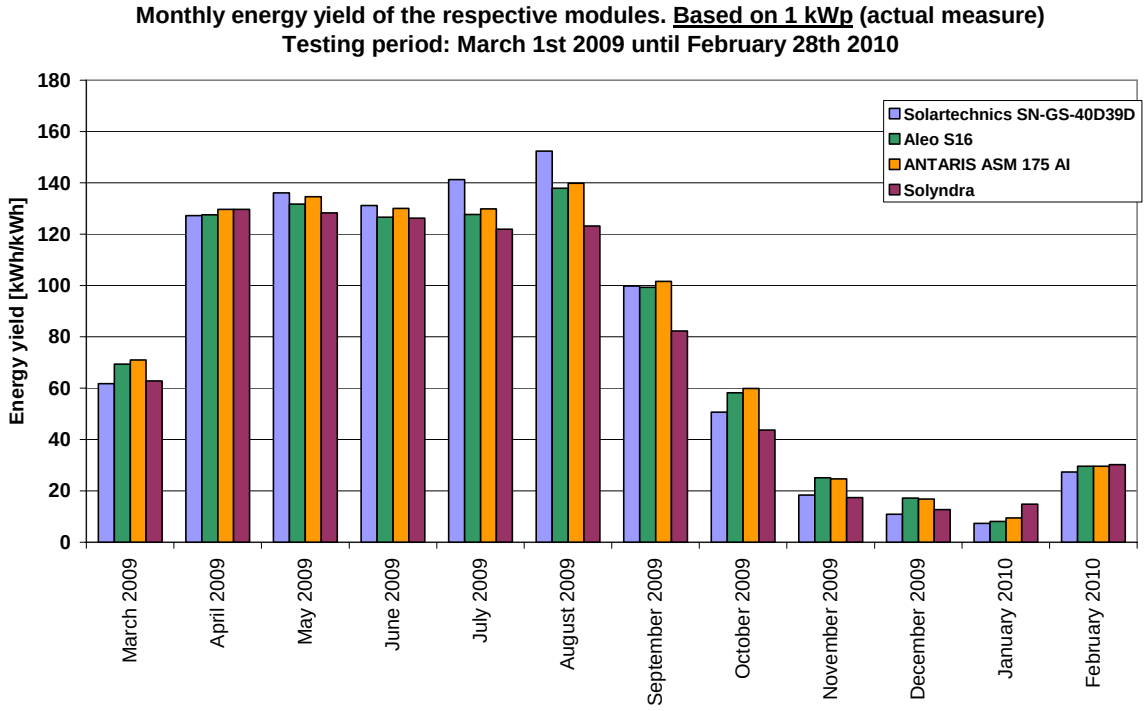

Fig. 7: monthly output [kWh/kWp]

Only in January, Solyndra is distinctly ahead of the other modules. The roof, and thus the modules were covered in snow over long periods of time in January. The snow melted relatively fast from the Solyndra module. Snow lying underneath it, reflected the light. This resulted in a comparatively high output, without any notable effect on the annual energy yield.

4. Analysis:

Observations per unit area:

For flat plate-modules, the expected energy yield per unit area (in this case per m^2) can be determined from the nominal power output values on the datasheet. In connection with this, performance of the cylindrical module is especially interesting. Fig. 8 shows the percentage of expected energy yield per square meter as well as the percentage of effectively generated annual yield in relation to monocrystalline (100%).

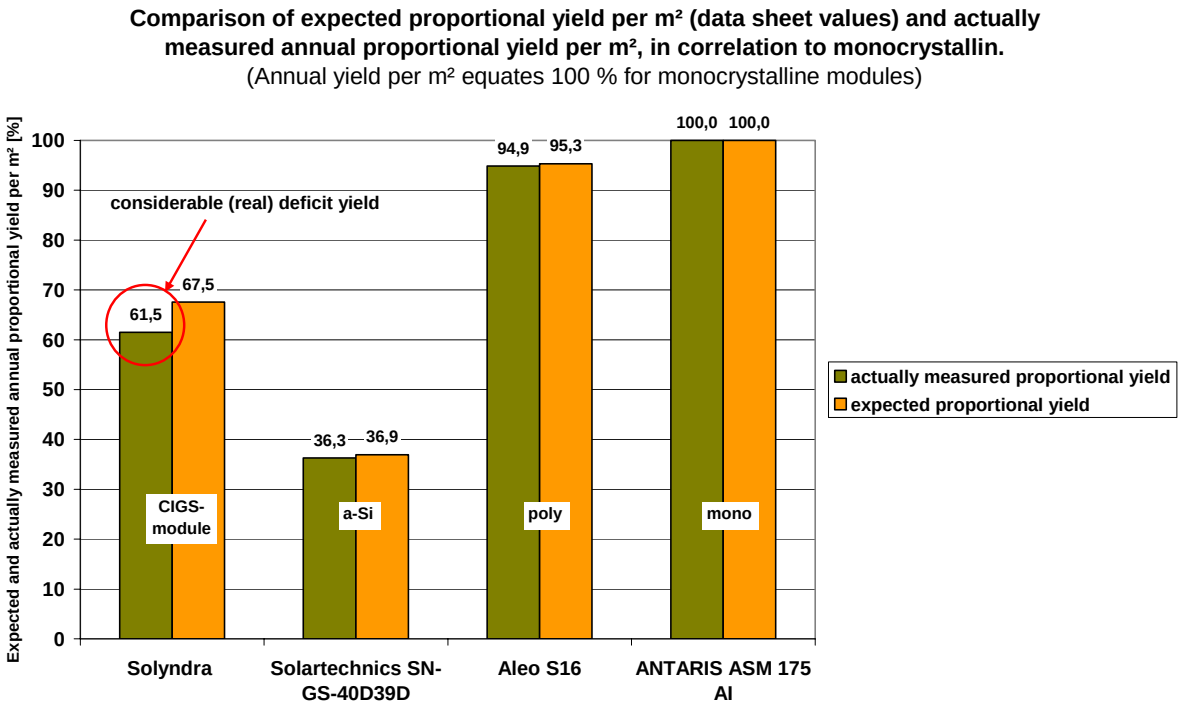

Fig. 8: comparison of expected and actual proportional yield

Results:

While the actually measured annual proportional yield divides among monocrystalline, polycrystalline and a-Si flat plate-modules, exactly as predicted by the datasheets (max. deviation 0.6%), the Solyndra cylindrical

module deviates considerably. The measured energy yield remained 6% lower than the energy yield which was to be expected according to the datasheet.
If you are used to calculating your demand of space, and thus your energy yield, referring to the data sheet, as with conventional flat-plate modules, you will have to expect some demand for extra space. The CIGS-cylindrical module Solyndra needs considerably more space (6%) to achieve the desired output.

5. Conclusion:

It is a great disadvantage, that the module shades its own reflector (see fig. 4). Furthermore, the white reflection film smudges very fast, and in central European weather conditions needs cleaning several times a year, in order to reflect optimally. This was the case with the film we used at least, which was the one delivered by the manufacturer. The cleaning process can pose a problem on larger roof surfaces covered with Solyndra modules. It is difficult to reach underneath the modules with the cleaning equipment.
Surely, there a lot of potential for development within the CIGS technology, which might lead to efficiency enhancement in the future. At the moment the considerably higher price, together with the lower specific output make for a big disadvantage.

6. Equipment

Equipment:	**Type:**	**Manufacturer/Supplier:**
Multimeter	Fluke 45	Fluke
Multimeter	Fluke 89 IV	Fluke
Inverter	Soladin 600	Mastervolt
Electrical Network Monitoring	ENS 26	UfE
Measuring computer	GX 260	Dell
Software	MS Visual Basic 6.0	Microsoft
Software	MS Excel 2003	Microsoft
PV-module	SL-001-182 C	Solyndra
PV-module	SN-GS-40D39D	Solartechnics

PV-module	S 16	Aleo
PV-module	ASM 175	ANTARIS

Waldaschaff, 13th of April 2010

Eberhard Zentgraf
Qualified Electrical Engineer. (FH) Eberhard Zentgraf
TEC Institute of Technical Innovation