Published in SolarNet Magazine, Volume 2, Number 2, 2000

Amorphous Silicon PV Panels: Are they a good value for the money?

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August 10, 2000

Introduction: A Market on the Move

It is estimated that over 100,000 rural Kenyan families are using a solar energy to generate electricity in their homes. The majority of these families have chosen to buy a small (12 or 14 Watt) amorphous silicon photovoltaic (PV) panel to generate this power. In the late 1990's sales of these amorphous silicon (a-Si) PV panels ranged from 12,000 to 20,000 units per year, depending on the state of the economy, and average sales growth of a-Si PV in the 1990's approached 30% per year. Equally exciting and important, the market for solar systems in Uganda is now taking off as it did in Kenya, and if properly supported, this pattern could spread to other nations in eastern Africa and indeed in sub-Saharan Africa generally.

Until very recently, three European based manufacturers accounted for nearly all of the sales of a-Si PV modules in Kenya. "Free Energy Europe" (FEE) manufactures panels that are rated at 12 Watts in its factory in France, while "Intersolar" makes 14 Watt rated panels in the United Kingdom and "Koncar" makes 12 Watt rated panels in Croatia. The most important reason for the commercial success of these small panels is their low cost compared to the other types of panels available in the Kenyan PV market. FEE's 12 Watt panel sells in shops for 4,000 KSh, which corresponds to 333 KSh per rated Watt, while Intersolar's 14 Watt panel often sells for about 5,000 KSh, or 357 KSh per rated Watt. For comparison, small crystalline PV modules generally sell for 650 KSh per rated Watt.

However, despite their commercial success, there has been much concern in Kenya and around the world about the quality of these small a-Si PV panels. To address this concern, our group carried out a research project in 1999 to test the performance of the panels. The collaborative research team included participants from Energy Alternatives Africa (EAA) of Nairobi, and the University of California, Berkeley and Princeton University, both of which are located in the United States of America. The research was generously funded by the Dexter Trust of the city of Chicago in the USA.

From March to July of 1999 we visited 145 families that were using solar PV for household electricity. We tested PV panels owned by families in rural areas near Nanyuki, Nyeri, Chuka, Bungoma, Webuye, and Kisumu. We also purchased some new a-Si PV panels in Nairobi, which we tested for performance over time at EAA's office in Nairobi as well as at the University of California, Berkeley in the USA. In total, our

group tested 130 working a-Si PV panels. In addition, we found 23 panels in the field that had cracked or failed. Finally, we tested 17 crystalline PV panels in the field in Kenya in order to compare their performance to that of the a-Si panels.

Our test results indicate that a-Si panels made by Free Energy Europe and Koncar perform well when compared to crystalline PV panels, but the Intersolar panels that we tested performed well below acceptable standards. However, Intersolar has taken a number of steps to improve their panels in the last year, and the preliminary tests that we have done on their new modules in the last few months do show that they are better than the ones that we tested in 1999. We will continue to test these new Intersolar modules, and we will publish the results in this magazine as they become available.

What is the difference between a-Si PV and crystalline PV panels?
There are a number of different types of photovoltaic panels. The two main types available in Kenya are (1) crystalline silicon PV and (2) amorphous silicon PV. The crystalline PV panels can be further divided into mono-crystalline and polycrystalline PV, and the amorphous silicon panels can be divided into multi-junction and single junction amorphous silicon PV. While all of these technologies can be used to generate electricity from solar energy, there are some differences in the way that they are manufactured, and these differences affect their cost as well as the way that they perform. Our research focused entirely on the performance of the single junction a-Si modules that are available in Kenya, but it is useful to understand how these panels differ from the other types that are available.

Crystalline PV panels were first invented in the 1950's, and the technology now has a well deserved reputation for high quality performance. Most brands of crystalline PV modules are rugged enough to last 20 years or more. By comparison, amorphous silicon PV panels are relative newcomers. They were invented in the mid-1970's, and they were first made commercially available by the Chronar Corporation (USA) in the mid-1980's. The a-Si technology has a mixed reputation for performance, although some brands have clearly demonstrated that they manufacture high quality products. In particular, several brands of multi-junction a-Si panels have good reputations for quality. These include triple junction a-Si modules made by Unisolar and the double junction "Millennium" a-Si PV modules made by BP - Solarex. The research results that we present here show that some manufacturers of single junction a-Si modules also make high quality products.

One of the main technical differences between crystalline and amorphous PV technologies is in their efficiency at converting solar energy into electricity. Crystalline PV panels now have efficiencies that range from 8 to 15%, while single junction a-Si modules often have efficiencies that range from 2 to 4%. For most rural consumers, these differences in efficiency are *not* very important. The efficiency of a panel tells you how much electricity it can generate for a given amount of area. This means that an a-Si 12 Watt panel will be larger in size than a crystalline panel with the same 12 Watt rating. But most rural families have plenty of space on their roofs for PV panels, so the lower efficiency of the a-Si panels is not a problem.

A second difference between a-Si and crystalline PV has to do with their performance during the first few months after they are purchased. For a given amount of sunlight, the performance of crystalline PV panels is more or less constant from the time that they are bought. In contrast, most a-Si panels lose about 25% of their output during the first few months of use. After that, the performance stabilizes at a constant level. The final "stabilized" performance is supposed to be equal to the manufacturers "rated" performance, so a 12 Watt panel should start out at about 15 Watts when it is new and then drop to 12 Watts over the first few months of use. This initial loss of performance should not be a problem for Kenyan PV system owners, as long as the final "stabilized" performance is equal to the rated performance.

The final important difference between a-Si and crystalline PV panels in Kenya is their price. As we noted before, it is the lower price of a-Si PV that has convinced so many Kenyans to choose a-Si PV over the higher priced crystalline PV panels.

Amorphous silicon PV panels available in Kenya

The 12 Watt PV panels made by "Free Energy Europe" (FEE) are known to many in Kenya under the brand name "Neste Advanced Power Systems" (NAPS). FEE purchased the factory where these panels are made from NAPS in 1998. These panels have a thin black plastic frame, and the part number is model 11601. Prior to 1996, NAPS manufactured an 11-Watt panel that was widely available in Kenya. This older panel (model number A13R) had a silver aluminum frame, and is similar to in appearance to the Koncar 12 Watt modules (the NAPS panel had a label with the name "Neste", which is the best way to tell this one from the Koncar). In this article we will call the 11-Watt module the "NAPS", while we will call the 12 Watt module the "FEE".

The "Intersolar" 14 Watt panels are known in Kenya under the brand name "Phoenix Gold"; these panels (model number B108D) are characterized by their gold frames and black plastic frame corners. Prior to 1998, Intersolar made 11-Watt modules called the "Phoenix" (model number B107W) that are distinguished by their green plastic frame corners.

The "Koncar" 12 Watt panels can be distinguished by their silver aluminum frames (although see above for the similarity to the old NAPS 11 Watt panels). Many Koncar PV panels sold in Kenya do not have a label from the manufacturer, but they often have a sticker with the name "Sollatek" on the back (Sollatek is the name of the Kenyan based company that imported the Koncar modules).

Testing PV modules in Kenya

We tested PV modules using a carefully designed and accurate outdoor test method. The result of the test is a "current-voltage" curve (also known as an "I-V" curve) for each panel. The I-V curve can be used to estimate the maximum power output for each panel. This maximum power can then be compared to the manufacturer's rated power output to see if the panel is performing adequately.

In order to be sure that our test method was accurate, we send six of the panels that we had purchased in Kenya to the National Renewable Energy Laboratory (NREL) in the USA. This lab tested the modules using two different methods. One of the tests was done using a solar simulator that is similar to the type that is commonly used by PV manufacturers when they rate their panels. The other test used a simulator that is even more accurate than the ones typically used by PV manufacturers. The results of the tests done at NREL indicated that our test results are accurate to within ±5% of the actual performance of the PV panels. This means that we can be confident that our results are an accurate representation of the true performance of the modules that we tested.

How well do the different brands of a-Si PV modules perform?

We found large differences in the average performance of different brands of a-Si PV panels sold in Kenya. See Table 1 and Figure 1. Of the brands that we tested, a-Si PV panels made by NAPS (now FEE) performed best, panels made by Koncar were a close second in performance, and panels made by Intersolar were a distant third.

The average power output from the 12 Watt FEE panel was 10.6 Watts, or 89% of its rated output. The average output of the older 11 Watt NAPS panels was 9.7 Watts, or 88% of rated output. The 12 Watt Koncar panels produced, on average, 10.0 Watts (83% of rated). The average output of the older 11 Watt "Phoenix" panel made by Intersolar was just 6.8 Watts (61% of rated), and the average output of the 14 Watt "Phoenix Gold" panel was 7.7 Watts (55% of rated). Note that these average performance levels do not include any panels were cracked or that had failed completely.

It is somewhat troubling that, on average, none of the panel brands that we tested performed at their rated output levels. Nonetheless, the panels made by NAPS / FEE compare favorably with the 17 crystalline panels that we tested in the field in Kenya (see Figure 2). In fact, tests done by other researchers in the USA in a number of studies published since the 1980's indicate that many brands of crystalline and amorphous PV panels often perform 5-15% below their rated power output. These results suggest that the better performing brands of a-Si modules sold in Kenya do just as well as many brands of crystalline PV modules in terms of meeting their rated power levels.

What about failures of a-Si PV panels?

In addition to their low power output, the Intersolar a-Si modules appear to suffer from high levels of failure (we defined a failed panel as one that was producing less than 10% of its rated power). We found that 46% of the 11 Watt "Phoenix" panels and 40% of the 14 Watt "Phoenix Gold" panels that we encountered in the field had failed. In most cases the failure of these modules appeared to be caused by water leakage into the module. We also found cracked glass plates in several cases. In contrast, only 6% of the Koncar and none of the 11 Watt NAPS and 12 Watt FEE panels that we found had failed. The reader should note that these results are likely to underestimate the failure rate for a-Si PV panels in Kenya because many families probably return failed panels on warranty or throw them away. Our result are based on only those failed panels that families had kept around.

How do a-Si panels perform in the long term?
Although 85% of the a-Si PV panels that we found in the field were less than 5 years old, we did find some that were as much as 10 years old. We had sufficient data to make an analysis of the long term performance of the NAPS 11 Watt panels and the Koncar 12 Watt panels. This analysis suggested that the power output for these panels may drop by about 1% per year. It is possible, however, that small improvements in the manufacturing of these PV panels can account for the difference in performance between the older and newer panels.

Testing over an eight-year period by a government and utility supported research laboratory in the United States called PVUSA indicated that a drop in performance of 1-5% per year may be common for both amorphous and crystalline silicon PV technologies. This information in combination with our results suggests that the power output of the NAPS and Koncar a-Si PV panels may hold up just as well over the long term as the performance of crystalline PV panels.

Do warranties protect Kenyan customers from low performing PV panels?
All three of the manufacturers of a-Si PV panels sold in Kenya offer and honor warranties on their products. Free Energy Europe sells panels in Kenya with a 10 year warranty, while Koncar and Intersolar panels have a 5 year warranty. The terms on these warranties all guarantee that the panels will perform to within 90% of the rated power output for the period of the warranty. The evidence that our group has collected suggests that the importing agents for all of these panels have historically been cooperative about replacing panels that are returned on warranty.

However, there are some concerns about the practical value of these warranties to protect customers in rural Kenya. The main concern is that no one in the rural areas of Kenya, including the shops that sell the panels, is in a position to accurately measure the power output of PV panels. This means that rural families generally cannot determine if the performance of their panel is above or below 90% of rated power. The first sign of panel failure is battery failure, but batteries fail regularly even when used with a panel that is working properly. It is therefore often hard for families to know whether they should try to return their panel on warranty or not. As a result, many people return panels only when they have failed completely. This means that many Kenyan families currently own an a-Si PV panel that is performing below warranty specifications, but few of these families know that they are in a position to return the panel for a new one.

What is being done to improve the performance of a-Si PV panels?
Over the past decade, all three a-Si companies in our study have made changes in their manufacturing processes with the goal of improving the performance of their products. The strong performance of the NAPS / FEE PV panels suggests that NAPS and now FEE achieved great success in this area.

Although the poor showing of the Intersolar panels that we tested in 1999 is troubling, this company has made substantial investments in improving the quality of their products over the last year. In September of 1999 (about 2 months after we finished our field

tests) Intersolar introduced a new version of the "Phoenix Gold" 14 Watt PV panel, and this panel is now available in Kenya. These new panels look the same as the older version of the "Phoenix Gold", except that their frame is a brighter color of gold. Our group has been testing a sample of 4 of these panels that were sent to us by Intersolar, and preliminary results indicate improved performance. The average power output of the panels that we tested is approximately 11 Watts (just under 80% of rated). This still falls a bit short of the performance of the Free Energy Europe panels, but it is an encouraging improvement over the performance of the previous "Phoenix Gold" panel. In addition to the improved power output, Intersolar has taken steps to improve the sealing of their panels. Improved seals will help keep water out, which should result in fewer panel failures. Although we have not tested the new seals, they appear to be much better than the old ones. Finally, Intersolar claims that in recent months they have made still more improvements to their panels. Our group is testing the newest versions of the "Phoenix Gold" panels, and we will report the results here in "Solarnet" as soon as we have completed the tests (the tests take about 3 months, as we have to wait until the power output of the panels stabilizes).

a-Si PV panels can provide reliable, low cost PV to rural Kenyan families

The better performing a-Si PV panels sold in Kenya are the lowest cost PV panels available in Kenya in terms of the price per measured peak Watt. See Table 2. Among the panels that our group has measured, those made by Free Energy Europe are currently the least expensive panel available in Kenya, with a price of 377 KSh per measured peak Watt.

The strong showing of the Free Energy Europe and Koncar panels show that single junction amorphous silicon PV panels can provide a high quality but low cost alternative to crystalline PV panels. However, the difference in performance between the various brands of a-Si PV panels means that it is important for people who would like to buy a panel to choose carefully when they are at the shop. We hope that this article will provide information that will help potential customers and vendors to make wise choices between the available options.

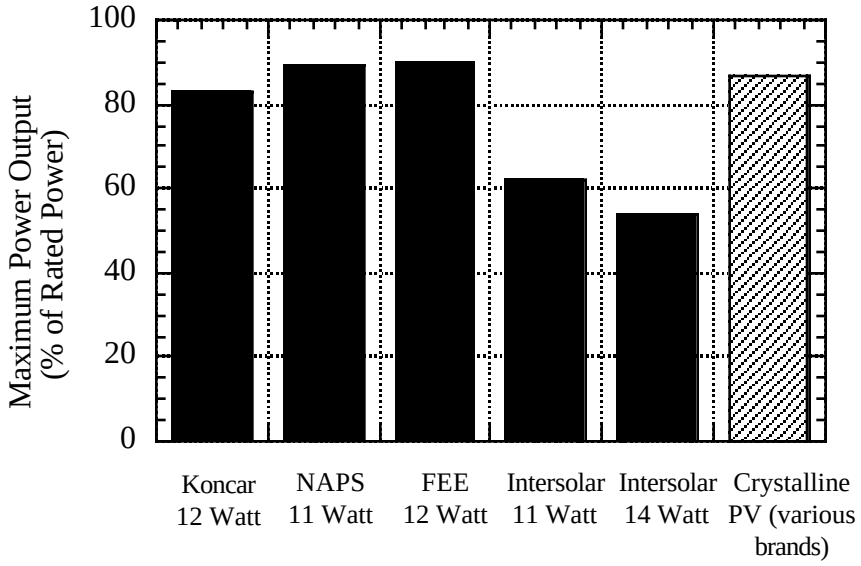

Figure 1: Average Performance for PV Panels Tested in 1999

Table 1: Performance Summary for a-Si PV Panels Tested in Kenya During 1999

Panel Type	Rated Max. Power (Watts)	Average Measured Max. Power (Watts)	Percentage of Rated Output	Average Age of Modules (years)	# Modules Tested
Koncar	12	10.0	83%	2.8	31
NAPS	11	9.7	88%	3.1	31
NAPS / FEE	12	10.6	89%	0.9	32
Intersolar "Phoenix"	11	6.8	61%	2.4	5
Intersolar "Phoenix Gold"	14	7.7	55%	1.5	12
APS	25	22.5	90%	5.0	1
Chronar	10	7.2	72%	5.9	4

Table 2: Typical Retail Prices for Some Small PV Panels in Kenya
(note that the price per measured Watt is based on performance results from 1999)

Module Brand	Module Type	Rated Power (Watts)	KSh per rated Watt	KSh per measured Watt
Free Energy Europe	a-Si	12	333	377
Koncar	a-Si	12	417	500
Intersolar "Phoenix Gold"	a-Si	14	357	649
Typical Crystalline PV	x-Si	20	600	686

Note: Readers that would like more details about our test methods and results or other information about our research should contact the us to get copies of additional reports and scientific papers that we have written.