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# Engineering, institutions, and the public interest: Evaluating product quality in the Kenyan solar photovoltaics industry

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## Abstract

Solar sales in Kenya are among the highest per capita among developing countries. While this commercial success makes the Kenya market a global leader, product quality problems have been a persistent concern. In this paper, we report performance test results from 2004 to 2005 for five brands of amorphous silicon (a-Si) photovoltaic (PV) modules sold in the Kenya market. Three of the five brands performed well, but two performed well below their advertised levels. These results support previous work indicating that high-quality a-Si PV modules are a good economic value. The presence of the low performing brands, however, confirms a need for market institutions that ensure the quality of all products sold in the market. Prior work from 1999 indicated a similar quality pattern among brands. This confirms the persistent nature of the problem, and the need for vigilant, long-term approaches to quality assurance for solar markets in Kenya and elsewhere. Following the release of our 2004/2005 test results in Kenya, the Kenya Bureau of Standards moved to implement and enforce performance standards for both amorphous and crystalline silicon PV modules. This appears to represent a positive step towards the institutionalization of quality assurance for products in the Kenya solar market.


*Keywords:* Solar energy; Market regulation; Africa

## 1. Introduction

The solar market in Kenya is among the largest and most dynamic per capita among developing countries. Cumulative solar sales in Kenya since the mid-1980s are estimated to be in excess of 200,000 systems, and annual sales growth has regularly topped 15% over the past decade (Jacobson, 2004). Much of this activity is related to the sale of household solar electric systems, which account for an estimated 75% of solar equipment sales[1] in the country (ESDA, 2003).

Despite this undisputed commercial success, product quality has been a significant concern in the Kenya market. The debate over solar module quality exploded publicly in May of 2004 in the form of a series of sensationalistic newspaper advertisements proclaiming that the low performance of a certain brand of amorphous silicon (a-Si) modules was a ‘‘solar panel scandal’’ (see Fig. 1). The advertisements sparked a heated debate about quality, consumer rights, and the ethics of negative advertising. Within a short time, though, the focus shifted towards a search for solutions. The results and events presented in this article represent a positive step towards resolving chronic quality problems that have plagued the Kenya solar market for more than a decade. The issues that emerged in Kenya, far from being an isolated case, are a precursor of what will likely take place elsewhere due to the international character of the global solar industry, and the degree to which Kenya has for well over a decade been a leader in this rapidly expanding technology sector.

In this study, we present performance test results for five brands of small a-Si modules that were widely available in the Kenya market during 2004. Our results indicate that while three of the five brands perform at or near their advertised levels, two brands perform far below their

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[1]The 75% figure refers to the fraction of solar sales on a peak kilowatt (kWp) basis.

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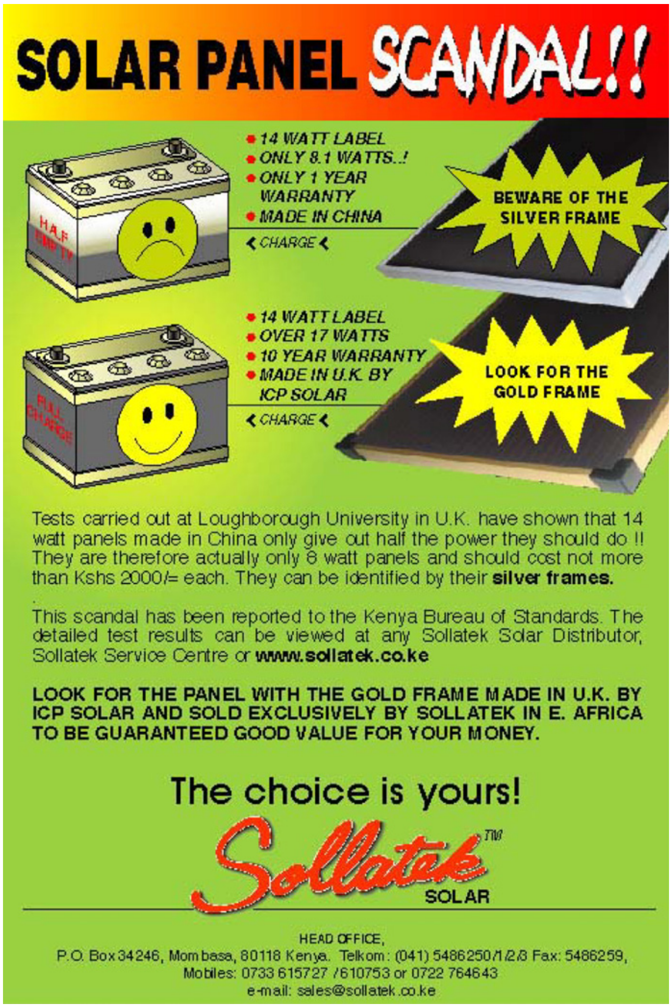


Fig. 1. "Solar scandal" advertisement in the Daily Nation newspaper, May 2, 2004.

nameplate power ratings.[2] The strong performance of the three leading brands supports previous evidence indicating that good quality a-Si PV modules can be an excellent value for the money. At the same time, the very low performance of the two remaining brands is troubling, as many consumers in Kenya and elsewhere lack the information to distinguish among the various competing brands. There is, therefore, a need for market institutions that ensure the quality and performance of solar products sold in the Kenya market.

This conclusion is strongly supported by a series of performance tests that we have conducted on a-Si modules in Kenya dating back to 1999.[3] The 1999 study played an important role in pressuring low performing brands of a-Si modules to improve or exit the market, while it also verified that most brands of a-Si modules performed well. The result was a stronger solar market and a better served public. However, within a few years a new line of low performing a-Si modules entered the market. This confirms the need for vigilant quality monitoring. In other words, the mix of high and low performing brands identified in the recent 2004/2005 tests is nothing new, and we should not expect performance problems to go away on a permanent basis even with the removal of the current low performing brands. In the absence of a vigilant and effective quality assurance program, performance-related problems are likely to re-emerge in the future.

## 2. A brief history of a-Si testing in Kenya

Amorphous silicon solar modules entered the Kenya market in 1989. Sales grew rapidly, and by the late 1990s a-Si modules had gained a significant share of the overall solar PV market in Kenya. See Fig. 2 for a record of amorphous and crystalline PV sales in Kenya from 1987 to 2001.

Although the high sales figures indicate commercial success, a-Si technology has had a mixed reputation for quality in Kenya (e.g. see Ochieng, 1999). The first generation of a-Si modules sold in Kenya were made by the Chronar Corporation, which went bankrupt in the mid-1990s in part due to quality related reputation problems (e.g. see Crawford, 1997). Several of Chronar's successors made high-performing a-Si modules, but low-quality versions of the technology also continued to be sold. This situation created a serious problem in the market, as many potential solar customers were unable to determine, which brands performed well and which did not (Duke et al., 2002).

The debate about quality led to a study of a-Si module performance in 1999. This joint study was carried out by researchers from the University of California at Berkeley (UCB) and Princeton University of the US in collaboration with Energy Alternatives Africa (EAA) of Nairobi.[4] In the context of this study, we carried out a field study that included performance measurements of 130 a-Si modules and 17 crystalline modules at 145 homes in rural Kenya. In addition, we also purchased 14 new a-Si modules in Nairobi that we tested at outdoor testing facilities in the US and Kenya.

## 3. Measurement method

We measured the modules in both the 1999 and the 2004/2005 studies using an outdoor IV curve testing method. The tests involve measuring current–voltage (IV) curves for each module on a clear, sunny day. The results for each

[2]Both of the low performing "brands" were manufactured by the same company, although they were sold under different brand names in Kenya. They can therefore be considered to be a single line of modules.

[3]See Jacobson et al. (2000a, b), Duke et al. (2000), Jacobson et al. (2001), Jacobson (2002), Duke et al. (2002), and Jacobson and Kammen (2004) for results from previous solar testing efforts in Kenya. These papers are available online at http://socrates.berkeley.edu/~rael/papers.html#PV and http://www.humboldt.edu/~aej1.

[4]The authors of this study were two of the key participants in the 1999 study. Note that EAA has since changed its name to Energy for Sustainable Development, Africa (ESDA).

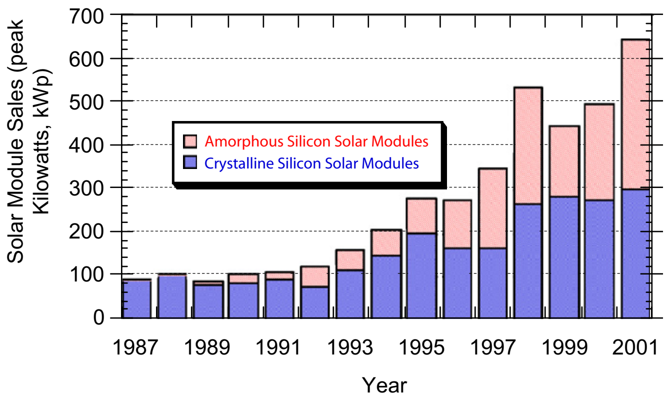


Fig. 2. Solar module sales from 1987 to 2001. *Data sources*: Hankins and Bess (1994), Hankins (2000), ESDA (2003).

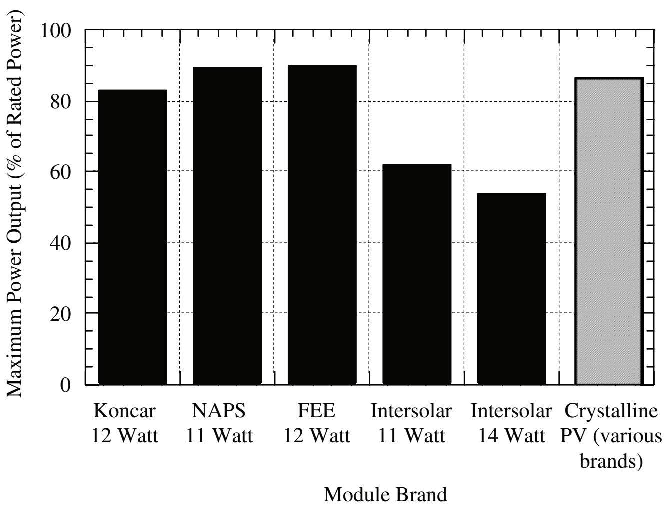


Fig. 3. Average performance for solar PV modules tested in 1999.

curve are normalized to standard test conditions (STC, $1000\,W/m^2$ and $25\,^{\circ}C$) using widely accepted equations. We use these normalized curves to estimate the maximum power output for each module for STC. The estimated uncertainty of the resulting maximum power performance of solar modules evaluated using this method is $\pm 10\%$.[5] See Jacobson et al. (2000a) for a more detailed description of the method.

The results of the 1999 and 2004/2005 studies are based primarily on measurements of the power output of modules that have been exposed to solar radiation for at least three to six months. In the case of the 1999 field measurements, the exposure was often significantly longer, depending on when the module had been put into use. This point is important because the performance of a-Si modules decreases during the first few months of exposure to the sun before stabilizing. This drop in performance is commonly called "Staebler–Wronski degradation" after the researchers who first identified the effect (Staebler and Wronski, 1977). Because the amount of Staebler–Wronski degradation often varies from brand to brand, it is critical to base comparisons of a-Si modules on their final, stabilized performance after 3–6 months of exposure to the sun.[6]

## 4. Amorphous PV performance results from 1999

At the time of the 1999 study, the large majority of the a-Si modules sold in Kenya were manufactured by three competing companies. The results of the study, which are summarized in Fig. 3, indicated that a-Si modules made by two of the three companies (Free Energy Europe[7] and Koncar[8]) performed reasonably well, while modules manufactured by the third company (Intersolar[9]) performed well below their advertised levels. Additional performance results are provided in Table 1.[10]

These results indicated that the high-performing brands of a-Si modules were an effective, low cost alternative to crystalline PV. However, the poor performance of the low performing brand indicated a need for measures to ensure the high quality of all modules sold in the Kenya PV market.

## 5. Response to solar PV quality in Kenya following the 1999 study

Intersolar made considerable investments to improve the performance of its a-Si products in the years following the 1999 study. These investments resulted in improved performance over time, as documented in Fig. 4. These results represent a significant success story, as the low performing Intersolar modules of the 1990s have been replaced with the current generation of high performing ICP-Solar a-Si modules. However, while the improvements

[5]The $\pm 10\%$ value is a conservative estimate of the uncertainty in the maximum power of the PV modules. This value is based on two types of error analysis. First, we estimated the overall uncertainty by considering the contributions to the uncertainty associated with each of the measurements used to calculate the maximum power of the modules. This approach resulted in an estimated uncertainty of $\pm 7.9\%$. Second, we sent six of the modules that we had tested to the National Renewable Energy Laboratory (NREL) in Golden, Colorado. These modules were tested at NREL using a "Large Area Continuous Solar Simulator" (LACSS, Spectrolab $200\times$). Our measurements of the maximum power for the six modules agreed with those made by NREL to within $\pm 6.2\%$.

[6]Crystalline silicon PV modules also experience a small amount of light induced degradation (generally on the order of 3–5%), but they typically stabilize after less than a month of exposure to the sun (Green, 2005; Cereghetti et al., 2003). As a result, evaluating the power output of crystalline silicon modules does not require several months of light soaking, as is required in the case of a-Si modules.

[7]Free Energy Europe (FEE) purchased the factory in France where its a-Si modules are manufactured from Neste Advanced Power Systems (NAPS) in 1998 (Duke et al., 2000).

[8]Koncar modules are now sold in Kenya under the brand name "Solar Cells".

[9]Intersolar was purchased by ICP-Solar in 2003 (Lane, 2003).

[10]See Jacobson et al. (2000a, b), Duke et al. (2000, 2002) for more information about the study.

Table 1
Performance summary for a-Si PV panels tested in Kenya during 1999

| Panel type | Rated max. power (W) | Average measured max. power (W) | Percentage of rated output (%) | Average age of modules (years) | # Modules tested |
|---|---|---|---|---|---|
| Koncar (Solar Cells) | 12 | 10.0 | 83 | 2.8 | 31 |
| NAPS | 11 | 9.7 | 88 | 3.1 | 31 |
| Free Energy Europe | 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 |

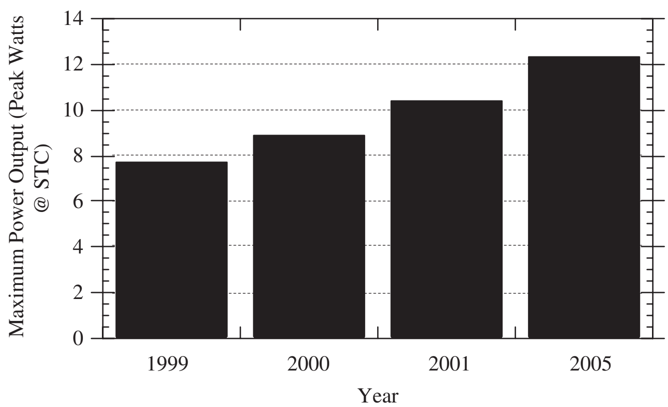


Fig. 4. Performance trend for 14 W rated Intersolar/ICP-solar modules from 1999 to 2005. (The performance data for 1999 are from field tests of the 12 Intersolar "Phoenix Gold" modules included in the Berkeley-Princeton-EAA study. The 2000 and 2001 results are based on measurements of two separate batches of four "Phoenix Gold" modules by author Jacobson at UC Berkeley. The 2005 results are based on the performance of the four ICP-Solar module included in the current study.)

made by Intersolar and ICP-Solar are very encouraging, these gains did not, as we explain below, eliminate the quality problems with a-Si technology in the Kenya solar market.

Several years after the 1999 study, a new line of low performing a-Si modules began to enter the Kenya solar market in significant quantities. The presence of these modules eventually led to the tensions described above that came to a head in the first half of 2004. The re-emergence of quality problems in the Kenya market confirms that the issue cannot be solved decisively by one time testing efforts, nor by focusing on the improvement of individual low performing brands. Rather, institutional solutions that persistently require high performance for all brands are needed to ensure quality.

In the years following the 1999 study, the Kenya Bureau of Standards (KBS) worked in collaboration with the Kenya Renewable Energy Association (KEREA) to draft performance standards for a range of solar products, including but not limited to amorphous silicon solar modules. By 2003, the committee in charge of developing the standards had approved a set of performance standards for both amorphous and crystalline PV modules that drew heavily from the respective codes established by the International Electrotechnical Commission (IEC).[11] The KBS did not, however, have access to the necessary equipment or technical capacity to carry out the specified tests. In addition, perhaps due to financial constraints, the KBS chose not to send modules for testing at internationally accredited testing labs outside of the country. As a result, the standards, while adopted, remained largely unenforced. Thus, while the move to draft and adopt performance standards may have represented a positive step towards an institutionalized approach to quality assurance, the adoption of unenforced standards did little to protect the interests of Kenyan consumers.

## 6. Amorphous silicon PV testing in 2004/2005

The results presented in this article are based on tests of five different brands of a-Si solar PV modules sold in Kenya. These tests were carried out at Humboldt State University (HSU) and the UCB between September of 2004 and March of 2005. In implementing this project, we worked in conjunction with the Kenyan Renewable Energy Association (KEREA), as well as Kenyan-based import companies who sell the various brands of amorphous silicon (a-Si) modules included in the study. In particular, KEREA coordinated a series of discussions within the Kenyan solar energy industry about solar module quality, while the solar import companies contributed funds to cover the costs of buying the modules and shipping them to the USA. Researchers from HSU and UCB coordinated all of the field activities related to selecting and purchasing the solar modules from retail shops in Kenya. We were assisted in this work by Maina Mumbi of Off-Grid Energy Alternative Technologies.

[11]The relevant IEC standard for crystalline silicon PVmodules is IEC 61215 (IEC, 1993), while the standard for amorphous modules is IEC 61646 (IEC, 1996). The corresponding Kenyan standards are KS 1674 and KS 1675. See http://www.iecee.org/pv/html/pvcntris.htm for more information about the IEC.

## 7. Sample selection

We selected four modules for each of the five brands of a-Si modules in this study by purchasing them from retail shops in Kenya.[12] See Table 2 for information about the five brands included in the 2004/2005 study. After selection, representatives from each of the respective import companies were given an opportunity to inspect the modules. All of the modules included in the tests were carefully inspected and were found to be free from visible physical defects.[13] According to the labels on the modules, all of the brands are nominally rated at 14 W. However, several companies have indicated that this value does not correspond to the maximum power at STC, and that the correct STC rating for their brand is 12 W.

Table 2
Brands of a-Si solar modules included in the 2004/2005 study

| a-Si module brand | Kenyan import company | Country of origin |
|---|---|---|
| Free energy europe | Chloride exide, Telesales | France |
| ICP-Solar | Sollatek | UK (Wales) |
| Shenzhen Topray #1 (eSolar)[a] | Kenital | China |
| Shenzhen Topray #2 (SunLink)[b] | Electric link | China |
| Solar cells | Bhatt electronics | Croatia |

[a]These modules were imported by Kenital from the Shenzhen Topray Solar Company. They were sold by Kenital under the "eSolar" brand name in Kenya.

[b]These modules were imported by Electric Link from the Shenzhen Topray Solar Company. They have been sold under at least two brand names in Kenya, including "SunLink" and "SunSolar."

## 8. Performance test results

The final, stabilized average maximum power output for each of the brands is given in Fig. 5. These results indicate that the performance of three of the brands (Free Energy Europe, Solar Cells, and ICP-Solar) is consistent with what one would expect from high performing 12 W solar PV modules. The performance of the remaining two brands (eSolar and SunLink), both of which were procured from the same manufacturer in China, is well below their advertised level of performance.

The data in Table 3 provide additional information about the relative performance of the five brands of a-Si modules. In the case of the high-performing brands, all three began the process with a maximum power output that exceeded the nominal 14 W rating on their nameplate. The average initial performance of the ICP-Solar modules was particularly high at 17.2 W. As expected, the performance of all of the brands dropped over the first few months of exposure to the sun due to Staebler–Wronski degradation, and the final performance for the three top brands is consistent with the performance of modules that have a maximum power rating at STC of 12 W.

It is notable that that the final performance of all three of these brands is close to 12 W despite the differences in their initial performance. This confirms that the rate of Staebler–Wronski degradation differs from brand to brand. In this study, the average performance of the four ICP-Solar modules dropped by 29% prior to stabilization, compared to 21% for the Free Energy Europe modules and 20% for the Solar Cells modules. This highlights the importance of basing comparisons of relative performance

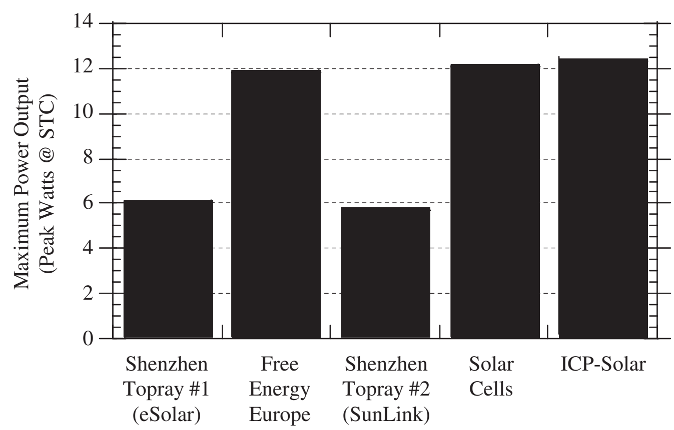


Fig. 5. Average stabilized maximum power output for five brands of 14 W rated amorphous silicon solar modules sold in Kenya. (Maximum Power at Standard Test Conditions, STC, of 1000 W/m$^2$ and 25 °C.)

on the final stabilized performance rather than on the initial power output.

It is also important to note that the relative performance of all three of these brands is statistically identical. In other words, although the average performance of the four ICP-Solar modules tested in the study (12.3 W) was slightly higher than the performance of the Solar Cells (12.1 W) and the Free Energy Europe (11.8 W) modules, these differences are well within the margin of error of the measurements methods used in the study.[14]

[12]Modules were purchased by our agent Maina Mumbi from retail shops in the towns of Narok, Molo, and Maai Mahiu as well as the capital city of Nairobi.

[13]The inspection was held in Nairobi on August 17, 2004. Representatives from four of the import companies attended, as well as representatives from KEREA, the Kenya Bureau of Standards (KEBS), and the University of California at Berkeley. One import company declined to send a representative.

[14]The 95% confidence intervals reported in Table 3 confirm this conclusion. These intervals indicate, with 95% confidence, that the average stabilized performance any Free Energy Europe module manufactured around the same time as the modules tested in the study is likely to fall between 10.7 and 12.9 W. Likewise, the range for Solar Cells modules is from 11.2 to 13.0 W, and the range for ICP-Solar modules is from 10.3 to 14.3 W. The fact that these ranges overlap indicates that we cannot be certain, based on the tests carried out in this study, which of the brands has the highest performance. A larger sample size for each module type would be required to determine differences in the relative performance of the respective brands.

Table 3
Summary performance results for five brands of 14 W rated a-Si solar modules

| a-Si Brand | # Modules in original sample | # Failed modules (March 2005)[a] | Avg. initial performance (Wp, STC) | Avg. final performance[b] (Wp, STC) | Final performance 95% confidence interval (Wp) |
|---|---|---|---|---|---|
| Shenzhen Topray #1 (eSolar)[c] | 4 | 3 | 9.1 | 6.0 | n/a[d] |
| Free Energy Europe | 4 | 0 | 14.9 | 11.8 | 10.7–12.9 |
| Shenzhen Topray #2 (SunLink)[e] | 4 | 1 | 9.1 | 5.7 | 5.4–6.1 |
| Solar cells | 4 | 0 | 15.2 | 12.1 | 11.2–13.0 |
| ICP-solar | 4 | 0 | 17.3 | 12.3 | 10.3–14.3 |

[a]Failed modules are defined as those with a maximum power output below 1 Wp as of March 1, 2005.
[b]The average final performance is based on the maximum power output of all "working" modules (i.e. modules that had failed outright were excluded from the sample for the purpose of estimating the average final performance).
[c]These modules were imported by Kenital from the Shenzhen Topray Solar Company. They were sold by Kenital under the "eSolar" brand name in Kenya.
[d]It was not possible to estimate a confidence interval for the final performance of the Shenzhen Topray modules sold under the "eSolar" brand, as only one module remained in operation.
[e]These modules were imported by Electric Link from the Shenzhen Topray Solar Company. They have been sold under at least two brand names in Kenya, including "SunLink" and "SunSolar."

One additional significant point is that, while the maximum power output of a solar module under STC is a key indicator of performance, other performance parameters such as durability and longevity are also important. In this area, Free Energy Europe deserves special credit for its "C-version" a-Si module, which has passed the rigorous set of tests required for IEC certification.[15]

As noted above, the power output of the two low performing brands is well below their advertised nameplate ratings. The average stabilized maximum power output at STC for both lines of Shenzhen Topray a-Si modules was approximately 6 W, which is well below acceptable levels for 14 W rated modules. The low performance of these modules may be caused by impurities introduced during production and/or other quality control problems in the manufacturing process.

In addition to low power output, we observed problems with module failure for both lines of Shenzhen Topray a-Si modules. In the case of the modules sold under the eSolar brand name, three of the four modules failed completely during their first few months on the test rack. One of the four modules sold under the SunLink brand name also failed during this time period. These failures appear to have been caused by water intrusion that led to delamination of the active material of the a-Si modules. See Fig. 6 for an illustration of this delamination.

[15]The "C-Version" of Free Energy Europe's a-Si module was certified according to the IEC 61646 standard. See http://www.free-energy.net/ and http://www.iecee.org/pv/html/pvstandards.htm for additional information.

Fig. 6. Water intrusion related delamination in a Shenzhen Topray a-Si solar module.

## 9. Response to a-Si performance results from the 2004/2005 study

Kenital, the company that marketed the Shenzhen Topray amorphous silicon modules under its eSolar brand name, responded to the results of this study by discontinuing sales of these modules. Kenital replaced the low performing modules with the Croatian made "Solar Cells" a-Si modules.

Electric Link, the other company that had been importing Shenzhen Topray modules, continued to sell the product for a number of months after being informed of its low performance. The KBS moved to enforce its existing quality standards for both amorphous and crystalline silicon PV modules in the month following the public release of the results of this study in Kenya. It was only at this point that Electric Link discontinued sales of the low-performing Shenzhen Topray modules. This highlights the

importance of an institutional and enforceable approach to quality assurance.

Currently, the KBS requires that import companies secure a certificate that validates that their product conforms to the respective Kenyan standards prior to bringing the modules into the country. This certificate of conformity must be issued by an accredited laboratory. No such facility exists in Kenya, so this testing takes place in laboratories in Europe, North America, and Asia.[16]

This approach represents a promising step towards an institutionalized approach to quality assurance for the Kenya solar market. While it is perhaps too early to draw conclusions about the long-term significance of these recent events, several solar manufacturers have already sought and obtained IEC certification as the result of this new requirement for participation in the Kenya market. At the same time, the lower performing brands appear to have been forced from the market.

These outcomes are important not only for Kenya, but also for solar markets elsewhere in Africa. One of the barriers to the regulatory approach that is currently being implemented in Kenya had been a dearth of small, low cost, IEC certified solar PV modules. In many African countries the solar markets remain too small to provide the government with sufficient leverage to induce solar manufacturers to pursue certification for the purpose of selling products in that country alone. The Kenya market, however, appears to have grown to a size where it can now successfully provoke such a response. Now that Kenya has taken this step, it should be easier for countries with smaller solar markets to follow suit. This suggests the possibility for significant spillover benefits from Kenya to solar markets elsewhere on the continent and beyond.

## 10. Amorphous silicon module performance and product labeling

One final issue of note is related to standards for labeling a-Si modules sold in Kenya. As mentioned above, the power output of the three high-performing brands of a-Si modules tested in the 2004/2005 study is consistent with modules that are rated to deliver 12 W under STC. This performance appears to differ from the nameplate power ratings of these modules, as all of the modules in the study were nominally marketed as 14 W modules.[17]

While some of the participating companies have indicated that they plan to change their labels to include information about the power output of the modules at STC, several company representatives have argued that they should be permitted to maintain the 14 W power rating.

One company, ICP-Solar, claims that the most recent version of its modules have a higher-performance level than the modules tested in the 2004/2005 study. They maintain that the new modules achieve a stabilized (i.e. post-Staebler–Wronski) power output of 14 W under STC, and that they therefore intend to report this performance on the product label. We have not tested this new version of the ICP-Solar modules, and we cannot, therefore, verify whether the modules that they currently market in Kenya achieve this level of performance.

Another argument in favor of maintaining the 14 W rating is based on the claim that at least some brands of amorphous silicon solar modules deliver approximately 15% more Watt-hours of electrical energy than crystalline solar modules for every Watt of power output at STC. In other words, the claim is that high-quality a-Si modules deliver more Watt-hours per peak Watt of rated power than crystalline PV modules.[18]

This claim is supported by a modeling study of the relative performance of several different types of amorphous and crystalline solar modules in a grid connected application in the Netherlands (Eikelboom and Jansen, 2000). The study indicated that a-Si solar modules manufactured by Unisolar and Free Energy Europe deliver approximately 12% to 20% more Watt-hours per rated peak Watt than several widely available brands of crystalline solar modules. Thus, some a-Si manufacturers argue that they should be allowed to increase the nominal power rating on their modules to account for the relative advantage in Watt-hour performance provided by high performing brands a-Si modules.

There are, however, several reasons to treat the results from the Eikelboom and Jansen study with caution. First, in the study they evaluated the relative performance of the technologies in a grid connected application that involved maximum power point tracking rather than in a battery based application. The relative performance of the respective technologies in battery based systems may vary significantly from the results presented in the study. Second, in the study, the performance of the various modules under low light conditions was estimated by tilting the modules at an oblique angle to the sun's beam on a clear day. Although this approach does not adequately simulate low light conditions associated with cloud cover, the modelers nonetheless used the oblique tilt measurements to estimate module performance for *all* low light conditions. This approach may result in significant errors in the estimate of the relative performance of the various modules under diffuse light

[16]See www.worldbank.org/astae/qpp/PVGAP/App8.pdf for a list of qualified facilities.

[17]According to standards adopted by the Kenya Bureau of Standards (KEBS), the power rating given on the label of solar modules marketed in Kenya should be the maximum power output at standard test conditions of 1000 W/m$^2$ and 25 °C (Kenya Bureau of Standards (KBS), 2003a, b).

[18]The reason for possible differences in the number of Watt-hours delivered per rated peak Watt may be related to the ability of a-Si modules to maintain higher efficiency at low light levels (e.g. on cloudy days) than crystalline modules. Additionally, a-Si modules suffer smaller voltage losses at high temperatures than crystalline modules. Both of these characteristics may contribute to differences in the relative performance over time of amorphous and crystalline solar modules (e.g. see Eikelboom and Jansen, 2000).

conditions.[19] Third, studies by other researchers have failed to replicate Eikelboom and Jansen's results. For example, Faiman et al. (2003) report results that appear to refute the claim that a-Si modules produce more energy per rated Watt than crystalline silicon PV modules. We therefore recommend the continued use of the KBS standard requiring that all solar PV modules be labeled according to their stabilized maximum power output under STC.

## 11. Conclusion

In this report, we present test results from 2004 to 2005 which indicate that the majority of the brands of amorphous silicon solar modules sold in Kenya perform well, and they remain a good value for their price compared to crystalline PV modules of comparable sizes. Free Energy Europe and Solar Cells brand modules deserve special mention for their long track record of producing consistently high-quality goods, while ICP-Solar merits credit for significant improvements in recent years. Our measurements indicate that the power output of these three brands is now similar, with each delivering approximately 12 W of power under STC.

However, we also found that modules imported from the Shenzhen Topray Solar Company performed well below their advertised levels. In response to these results, one of the import companies (Kenital) switched to a higher-performing brand, while the other (Electric Link) continued to sell the low-performing product for a number of months. This company discontinued sales only after the KBS moved to enforce compliance with previously unenforced standards.

Performance results for a-Si modules from 1999, in combination with the 2004–2005 measurements from this study, indicate that the presence of low-performing brands is nothing new in the Kenya solar market. Thus, while the 1999 study played an important role in pressuring low-performing brands to improve or exit the market, the 2004–2005 study verifies the need for ongoing vigilance if high-quality performance standards and consumer protection are to be maintained.

The recent move by the KBS to enforce performance standards represents a positive step towards an institutionalized approach to quality assurance. To date, this approach appears to have been successful, and cautious optimism may be warranted. Nonetheless, the history of recurring quality problems in the Kenya solar market suggests a continuing need for periodic independent testing efforts, as these have played a key role in promoting quality assurance.

In addition, there is a need to expand these testing efforts to other markets in the region. As solar markets develop throughout Africa, vigilant, effective, and transparent quality assurance programs are needed to maintain high performance standards and to protect the public interest.

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