REPORT ON 5 YEARS FIELD STUDY OF AMORPHOUS SOLAR PANELS

Abstract:

Amorphous Photovoltaic panels have been producing electricity since the early 1800's. In 1839 a Frenchman named Edmund Becquerel was noted for his work on the selenium Solar cell, which at that time was 1% efficient. Originally such cells produced only a few volts of electricity and were not feasible for major power production. More efficient cells were made from expensive materials such as Silver Oxide. Their use remained mainly for laboratory experiments and light sensors. Russia then began with Sputnik, in 1957, to put satellites into space, where the only continuous power supply was Solar Power. Later, Cheaper, Crystalline Silicon, PV panels were further developed in the 1950's, and the technology became feasible, compared to the **original, 1839** version, Amorphous technology. Amorphous Silicon, PV panels, for high power production, were further developed in the mid 1970's but they were only commercially available in the mid 1980's. The latest, most modern and most efficient, of the Solar Power producing systems, is the **Thin Film Technology**. Thin film, is Amorphous but not usually Silicon. Silicon is one of the worst materials, for Photovoltaic use but was used because it is very, very, cheap. Crystalline Silicon is becoming obsolete, as it is quickly being replaced by the new and better, Thin Film Technologies.

One of the main technical differences between crystalline and amorphous, PV technologies, is in their efficiency at converting solar energy into electricity. Do not confuse **"efficiency"** with **"Power output"** as efficiency bears no relation to actual power produced. Thin Film Amorphous, now has efficiencies around 25%. Crystalline Silicon PV panels have efficiencies that range from 8% to15%, while single junction a-Si modules often have efficiencies that range from 4% to 8%. This means that an a-Si, 12 Watt panel will be larger in size compared to a Crystalline panel with the same 12 Watt rating which will in turn, be larger than a

non Silicon, Thin Film, Amorphous panel, with the same 12 watt rating. **Note;** If output is 12 watts, it is **equal** on ALL types of panels and is not changed by efficiency of the panel. 12 watts at 100% efficiency is still the exactly the **same power** as 12 watts at 10% efficiency. The modern Amorphous silicon panel has shown good durability, long term stability and favorable long term performance based on a years of tests that have been done. Due to its very low cost and equal durability, to the new Thin film materials, it remains a viable alternative to Thin film technology when space is not a constraint. Crystalline panels, however have many problems and high cost, so will not be able to compete in the future of Photovoltaics.

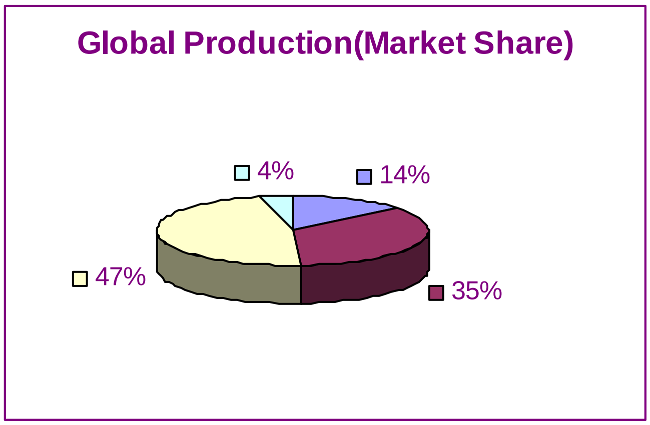
Amorphous Silicon, Solar Panels are the MOST, COST EFFECTIVE, power producers, of all Photovoltaics.

Today the Amorphous silicon panels are widely used around the globe. This is due to the way they have been manufactured, in order to provide better average performance than the crystalline panels. Thin film Panels are relatively new but are now purchased in large quantities around the world. Unfortunately some of the larger companies have bought up the Thin film and Amorphous, manufacturers and closed down most of the new plants. This is a great set back to the new technology.

Introduction:

The Amorphous silicon PV materials, offer substantial advantages over Crystalline PV materials and have huge cost advantages over both Thin Film and Crystalline technology. They typically, use less than 1% of the semiconductor material that is consumed in Crystalline products; they are also produced by techniques that are better suited for mass production and they require substantially less energy to manufacture. However, the statistics for the global production for the year 2001 show only the introduction, of the Thin film technology, into the market.

Year 2001



Amorphous Silicon	14%
Single-Crystal Silicon	35%
Polycrystalline Silicon	47%
Thin Film Amorphous. Gallium Arsenide, Cadmium Telluride, Copper Indium Diselenide	4%

While lower in sunlight-to-electricity conversion efficiency, to the more traditional c-Si or pc-Si PV modules, the significantly lower price of a-Si always, results in system savings, even though a slight, increased, area-related, installation cost might arise. If the installation area is big enough, **a-Si modules will provide more cost effective, PV solutions,** in most applications.

The demand for a-Si is increasing because of its relatively low-price, especially where there are no area constraints. Due to their pleasing visual appearance, the modules are well-suited for “building integrated” projects. Since there is still lack of end user familiarity and existing misconceptions, the usage of the amorphous silicon panels are still in a growing phase.

Performance Issues:

The two main issues of concern are durability and performance. Based on some earlier problems, the performance of the Amorphous silicon module was mistakenly, considered to degrade in performance, dramatically in comparison to c-Si and pc-Si. This misconceived ‘Stability Problem’ has been one of the major factors in reducing the level of acceptance of a-Si module technology. After a thorough 5 year experiment, done by the SMUD PV Program, and many other tests, it has been revealed that **the level of performance of the a-Si module is quite comparable and often better, than that of c-Si and pc-Si products.** The reason this particular issue is talked about is because the a-Si module is subjected to the Staebler-Wronski (SW) effect. When this effect takes place, there is a pronounced decrease in performance upon **initial** exposure of a new panel, to light, typically reducing the modules output by some 18%-20% compared to its **initial** output. This scenario will go on for the first few months and gradually the module will reach a ‘stabilized’ value. This will happen approximately 6 months after exposure. The problem only occurs when the original output is taken as the ‘rated value’ of output and performance, over time, is compared to that. The rated output value should be set at the stabilized value, after the SW effect has taken its course. **This means that there is no drop in output, <u>at all</u>, from the rated value, of Amorphous panels.**

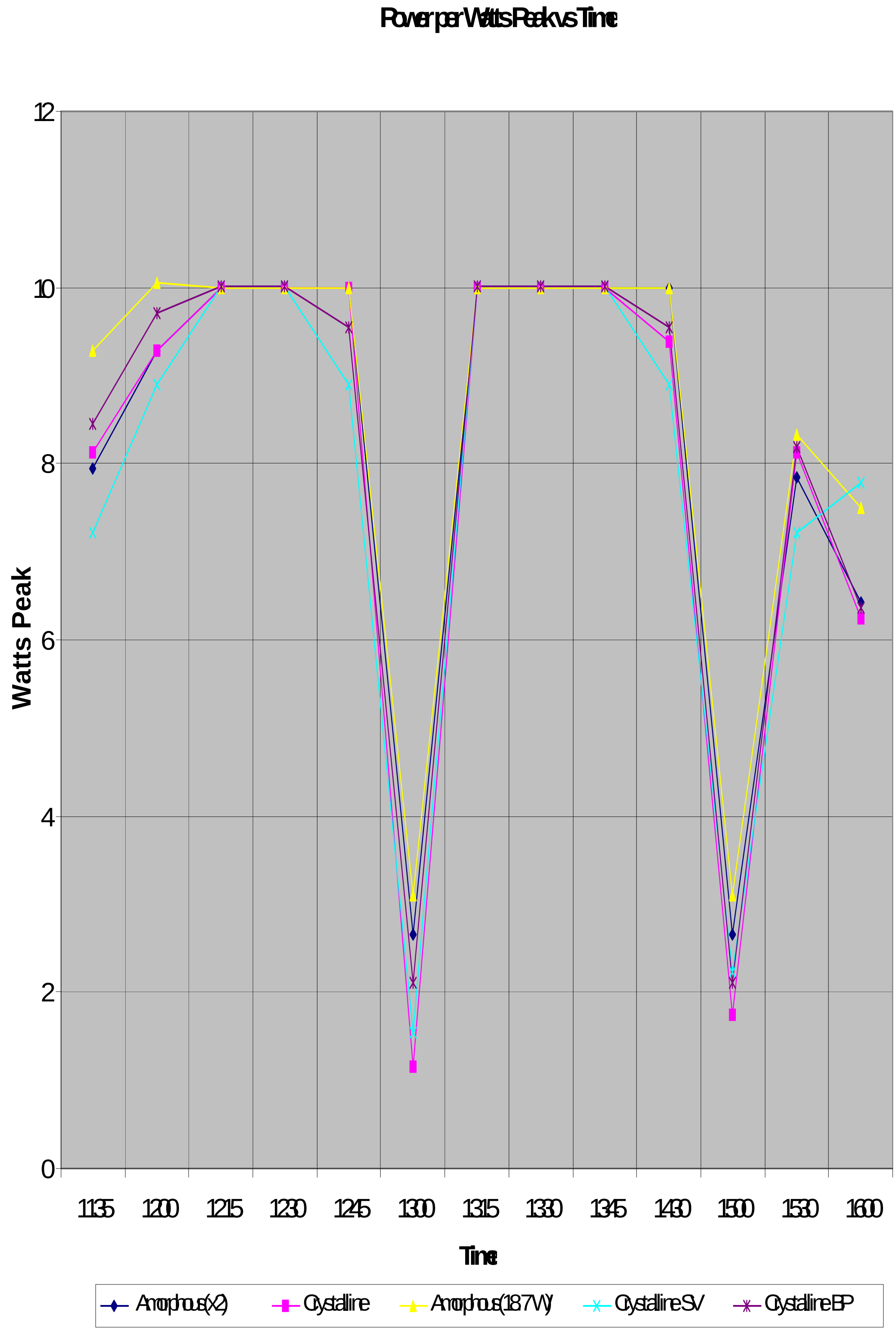
An extensive field experiment by the SMUD has shown that after a period of 3 months, a-Si modules operate at a point that is reasonably close to the stabilized value. After 6 months, the power is typically well within 10% of the stabilized value. A year is more than enough for a-Si modules to stabilize. Any changes after that period of time is due to either the long-term degradation of the module performance, which is LESS in magnitude to that of c-Si and pc-Si (typically less than 0.5% per year in hot climates).

Due to the annealing process of Amorphous panels, in Hot climates, the result is an INCREASE in output at certain times, giving the sinusoidal, season-to-season, fluctuation of module performance for a-Si modules. Thin film technology has no results for long term effects, due to its short length of time on the market. Results so far, are promising to give this technology the edge, over long term performance.

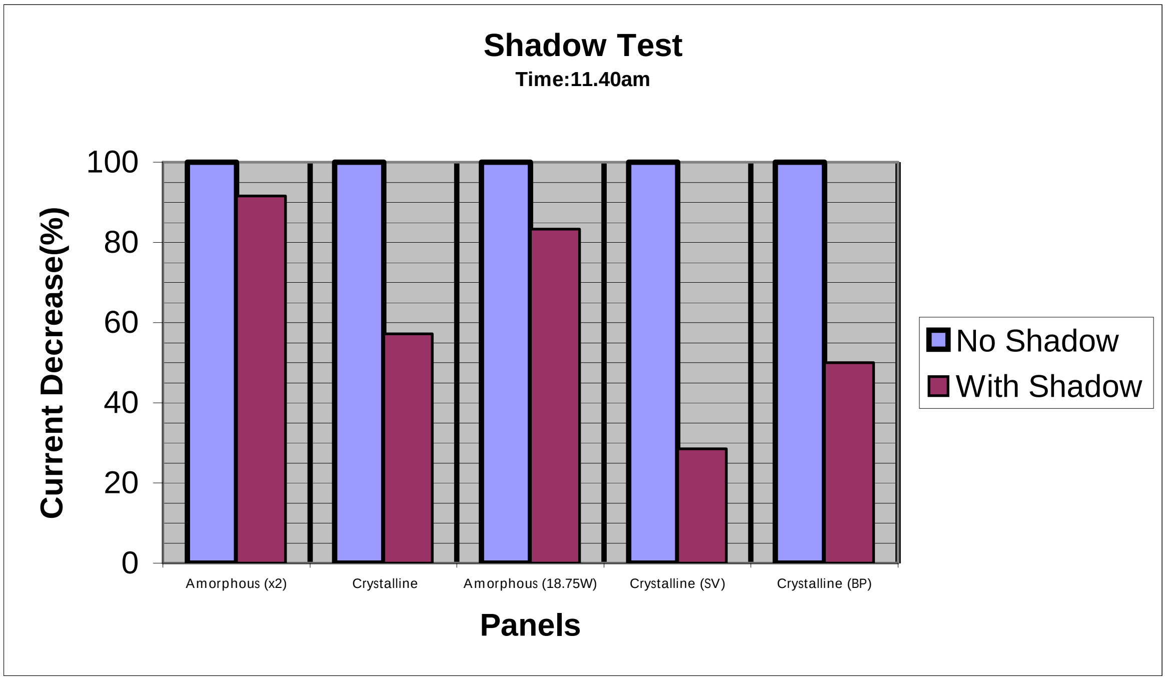
Malaysia is said to have a lot of Sunshine. Unfortunately this is not correct. **Malaysia has an average of 179 rainy days a year.** On non rainy days we also have a lot of cloudy days. **Sunny days average only 73 per year.** because of this, output of Solar panels, is much lower than many people calculate. There are many other reasons why actual output is less than expected. Another reason is that panel manufacturers, give you a graph, showing voltage, open circuit, against current, short circuit. Such a graph gives misleading information. For example, if you are charging a 12 volt battery, the graph will indicate that the rated voltage is say 18 volts, and rated current is say 1 amp. This, they will inform you, gives 18 watts of power. Unfortunately, when the voltage is **not** open circuit and the current is **not** short circuit, the output is completely different. When connected to a partly discharged battery, the 18 volt, panel voltage, will instantly drop and become the same as the battery. If the battery is partly discharged, this may be 11.5 volts. The current input, into the battery will be less also and will probably be about 0.8 of an amp, due to the resistance of the battery. That means that your graph indicates you will get 18 watts of power but you only get 11.5 volts at 0.8 amp which is only 9 watts. Remember that batteries lose 20% to 25% of the energy you put into them, so only 7 watts of power will be retrieved from these batteries, NOT 18 watts. Another important note to make, is that the graph given, is when the panel surface, is cooler than 25C and when the Sun is directly over the Panel, at mid day, when there is NO cloud and when it is not raining and is the very **Maximum** the panel will ever give*. (This is obviously impossible, as the Sun directly overhead, heats the panel to very high temperatures, well above 25C).* Because the panel is never operating under ideal test conditions, the graph is only relevant in the laboratory test condition specified. **It does not give the output under normal operating conditions.** This problem leads to more than 80% of installations having undersized panels and failing to run correctly.

Climate Condition:

For well designed and properly installed systems, Amorphous silicon systems, operating in different climatic conditions, can exhibit very high performance ratios. All systems exhibit a very stable operation after the initial degradation. Amorphous silicon and Thin Film, are particularly well suited to warmer climates compared to crystalline modules, due to the smaller negative temperature coefficient of a-Si compared to c-Si and pc-Si and due to the noticeable increase of thermal annealing of Amorphous panels, caused by higher operating temperatures, reversing the degree of initial degradation.



In the above graph, notice the massive power drop, when a dark cloud, passed overhead during the testing. This occurred twice during this test. Note that the power drop of the Amorphous Panel was lower as the clouds approached, compared with a much higher drop in the Crystaline Panel output. Also note that



during the passing of the cloud, the Amorphous panel gave an average of 60% more power than the Crystaline panels. It still gives equal power, when the Sun returns to both panels. If you were to consider the output for a day of continuous cloud, the Amorphous panel would be providing very much more power than its Crystaline counterpart. **Considering the Cloudy and rainy nature of The Malaysian Climate, Amorphous Panels will produce an average of 20% more power than the equivalent Crystaline panel.**

<u>Shadow Tolerance</u>

Crystalline panels have the individual crystals, arranged in series, so that the power from each crystal goes through the next, in a long chain of crystals. This gives great problems if any one piece of crystal is in shadow. A shadow tolerance test was done on Amorphous and Crystalline panels by allowing 8 inches of the shadow of a 3 inch diameter metal pole, to fall onto the panel surface. Both panels were side by side under identical conditions. The readings were taken before the shadow was cast, during the shadow, for 10 seconds and after the shadow was removed. See graph results above.

A second, shadow tolerance test was done by throwing a small leaf onto the panel. The same leaf was used on each panel.

The results show that All types of panels, give identical output in full Sunshine at low surface temperatures. All types of panel, tested, gave the same output, in the direct Sunlight.

It is clear from our test results that the Amorphous panels are much more efficient in cloudy conditions. As the light level decreased the crystalline panel lost its output very quickly. The Amorphous panel, however, kept up a steady power output of almost 90% more efficiency under low light levels. This means that light, cloudy days, have less effect on amorphous panels but will completely wipe out the output of the crystalline panels.

The shadow tolerance test showed very dramatic changes on the crystalline panel.

Crystalline and Amorphous panels showed the same output in direct Sunlight.
With 8 inches of shadow cast across each panel, the crystalline panel dropped dramatically in output. The Amorphous panel showed very little effect from the shadow and dropped only slightly. The leaf test gave the same results.
The crystalline panels have very poor shadow tolerance.

Overall, the amorphous panel gives more output per day, on average, per watt peak, than its crystalline counterpart.

Conclusion:

It is clear that thin film PV materials such as a-Si offer substantial potential advantages over the older crystalline PV materials. While Amorphous Silicon is lower in conversion efficiency compared to the more traditional single-crystal silicon(c-Si) and polycrystalline(pc-Si) PV modules, **amorphous silicon modules have demonstrated good durability, long-term stability and favorable long-term performance**. Non Silicon, Thin Film panels, demonstrate much higher efficiencies than all types of Silicon panel.

Efficiency is often misunderstood by the consumers, who are misled to believe, that a more efficient panel, will give more power, than a less efficient panel. Efficiency refers only to the SIZE or surface area of the panel and how efficiently the Sunlight is converted. Output, on the other hand, is the amount of power you will get from any particular panel. Example; a 100 watt rated, Crystalline panel gives you 100 watts of power. Similarly a 100 watt rated, Thin Film panel also gives you 100 watts of power and a 100 watt rated, Amorphous panel also gives you 100 watts of power. If you have a 100 watt light bulb it will run just the SAME on a 100 watts from a Crystalline panel, as it will on 100 watts from an Amorphous panel. **It makes no difference to the light bulb if the panel is 1% efficient or 100% efficient.** The 100 watts output will always be the same no matter what the efficiency of the panel producing it.

Another common misconception is the “watts peak” figure given by the panel manufacturer. **The watts peak does not refer to the ACTUAL output of the Solar Panel,** in operation. Actual output depends mainly on the amount of Sunlight reaching the panel, the angle of the Sun to the Panel, shadows or dust over the panel, the panel surface temperature, the resistance of the load and the local atmospheric conditions. In Malaysia’s Tropical climate, the average output of a Solar panel is only 60% of the watts peak value, and **less for Crystalline panels.**

References

1. Osborn, D.E., “SMUD: A Utility Helping to Create the Solar Century”, Renewable Energy World, September/October 2000.
2. Osborn, D.E., “Sustained Orderly Development and Commercialization of Grid-Connected Photovoltaics: SMUD as a Case Example”, Keynote Address, World Sustainable Energy Conference, Wels, Austria, March 2001.
3. Maycock, P, PV News, Vol. 21, No. 3, March 2002
4. Maycock, P., “The World PV Market: Production Increases 36%”, Renewable Energy World, July/August 2002.
5. Arizona State University Photovoltaic Test Laboratory (ASU-PTL), SMUD PV Module Test Reports, April/May 2002.
6. Delahoy, A., Li, Y-M., Selvan, A., Chen, L., Varvar, T., Volltauer, H., “Massive Parallel Processing for Low Cost A-Si Production”, PV in Europe Conference, Rome, 2002.
7. Osborn, D.E., "Instrumentation and Monitoring of a 3kWe PV Facility", Third World Conference on Microcomputer Applications in Energy (MAE '88), Tucson, November 1988.
8. Sandia National Laboratories, “Hardware Certification”, Quarterly Highlights of Sandia’s Solar Programs, Volume 1, 2002.
9. Gottschalg, R, Jardine, C.N., Ruther, R, et al, “Performance of Amorphous Silicon Double Junction Photovoltaic Systems in Different Climatic Zones”, 29th IEEE Photovoltaic Specialists Conference, New Orleans, 2002.
10. Ruther, R, Dacoregio, M.M., Montenegro, A.A., Knob, P., “The Performance of a Fully-Monitored, Double-Junction a-Si Grid-Connected BIPV System After Four Years of Continuous Operation in Brazil”, 29th IEEE Photovoltaic Specialists Conference, New Orleans, 2002.
11. Duke R. D., Jacobson A., Kammen D.A., “Product Quality in the Kenyan SHS Market”. University of California, Berkeley, 2001.

12. King, D., Kratochvil, J., Boyson, W., “Stabilization and Performance Characteristics of
Commercial Amorphous-Silicon PV Modules”, 28th IEEE Photovoltaic Specialists Conference, Anchorage, 2000.
13. US Department of Energy (with Committee of the US PV Industry), “US PV Industry
14.Roadmap”, 2001.
15. Millott P.D. Solar Voltaic Sdn. Bhd. Low “Average output, in field test conditions” compared to high “STC Watts Peak values”.