CIGS Photovoltaics Markets—2012

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About the Report:

The CIGS industry has promised more than it has delivered. To date, CIGS has failed to be the printable high-efficiency, low-cost and flexible solar panel technology that was once hoped for by its advocates. In addition, it is impossible not to notice that the Solyndra scandal in the U.S. has at its center a CIGS firm. Yet despite all this, the CIGS industry has begun to ship panels in significant quantities.

This report is NanoMarkets' latest report analyzing the CIGS industry and its prospects for the future. NanoMarkets has been covering the CIGS space since CIGS' earliest days and this report should be regarded as a major guide to the future of CIGS, compiled with an insider's knowledge. It examines the future of this important solar panel technology from both the standpoint of the technical and the commercial. And it does so with a background in which it seems likely that many of the subsidies that have helped solar in the past will fade away and that the world economy will not return to the strong growth of the last decade for quite some time.

Among the important technical aspects of CIGS that this report covers are the likely evolution of CIGS fabrication and encapsulation and how these factors factor into market expansion and cost reduction for CIGS. Much of the report is also devoted to the role that CIGS will play in the building-integrated PV (BIPV market) and how flexibility and price parity with silicon solar panels could considerably improve the revenues generated by CIGS technology in the near future.

As with most NanoMarkets reports, this report includes an eight-year forecast in volume and value terms of CIGS markets broken out by applications and product type. It also includes a discussion of the leading firms active in this space and their product/market strategies.

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Chapter One: Introduction

1.1 Background to this Report

Thin-film photovoltaic (TFPV) cells using Copper Indium Gallium Selenide (CIGS) as the absorber material have been promoted as the "next big thing" in PV for almost a decade.

After years of results that have been disappointing compared to consensus expectations, it is high time to take a sober look at the market for CIGS going forward in light of the current state of the technology and competitiveness of CIGS compared to other PV technologies. Other factors playing into the mix are the likelihood of decreased subsidies for PV going forward in North America and Europe, and the effect of significant increases in known reserves of natural gas, which have lowered and stabilized prices compared to the volatility and high prices seen in the 2007-2008 timeframe.

While there have been many disappointments for CIGS both with respect to the technology and its viability compared to competing products, the available data today is becoming much clearer with respect to:

- How close CIGS is to credible large-scale production than it has been before,
- Its price compared to other technologies, and
- The reliability of CIGS modules in real world applications.

As the efficiency of CIGS material is the highest of the thin-film PV absorbers, and it can be made into flexible modules, the key area where CIGS seems poised to dominate is in the building integrated photovoltaic area (BIPV). Here its light weight and efficiency, which increases the amount of electricity generated per area, are significant advantages over competing technologies.

While some start ups in the field such as Solyndra have imploded, other large manufacturing firms have aggressive CIGS product ramps planned. The increased competition from Taiwan and China will result in a shake-out in the industry, but ultimately will yield a price point that will likely lead to the adoption of CIGS in BIPV and others areas where module flexibility and high efficiency are key "care about" areas.

1.1.1 CIGS in a World of Reduced Subsidies and Economic Uncertainty

The value proposition of thin-film PV is clear. If it can be executed at a price point that is competitive with coal and natural gas, it provides a competitive more environmentally friendly though variable source of electricity.

While the current PV landscape is dominated by an oversupply of crystalline PV cells (crystalline PV module prices have fallen by 50% over the past eighteen months), the longer-term outlook for thin-film PV, and CIGS in particular, provides a compelling argument for this technology to be a significant factor in the PV landscape. CIGS is attractive for several reasons:

- CIGS uses more than an order of magnitude less absorber than crystalline cells;
- CIGS lends itself to flexible modules and roll to roll processing techniques; and
- It is the only thin film technology that approaches the efficiency of crystalline cells.

Any successful CIGS company will, however, have to be constantly innovating both to improve yields and aggressively cut manufacturing costs. Data over the past several years shows that all PV technologies are on an aggressive cost curve, and any technology or company that cannot stay on that curve will be doomed to failure.

Even though subsidies in the US and Europe may be diminishing, the commitment to subsidize solar energy in China may minimize the effect of reduced US and European government aid. China recently increased its solar surcharge to support solar and other renewables from .004 CNY to .008 CNY per kWh. China is committed to increasing their renewable energy portfolio to 15% by 2020. While not all of this growth will be thin-film solar, it represents a significant market that will be subsidized to meet this goal, regardless of the economic fundamentals compared to available fossil fuels.

1.1.2 What Does Low Cost Natural Gas Mean for CIGS Markets?

While the technical outlook for CIGS looks good from the perspective of being able to ramp production to significant volumes, an important question that needs to be asked with respect to demand is “Are the assumptions made about electrical prices from fossil fuels still as true today as they were in 2008, when oil and gas prices were extremely volatile?”

The short answer to the question: the assumption that natural gas prices will stay high and volatile has been shown to be wrong; new horizontal drilling techniques have greatly increased known reserves and created a landscape where oil prices will still be volatile, but natural gas prices will remain relatively low and stable for the foreseeable future. While at first blush it

might seem that this situation could negatively affect solar demand, NanoMarkets' opinion is that the affect will be negligible.

The new lower stable gas prices put natural gas in the same cost area as coal, and our opinion is that the stable gas prices will result in accelerated conversion of coal fired plants to natural gas, but little, if any, lowering of base electricity prices. While low-cost stable natural gas prices don't provide much cost benefit, switching from coal to natural gas reduces by half the amount of greenhouse gases emitted per MHW, and thus makes natural gas the choice for new base-load capacity.

So, overall prices for the fossil fuel base really won't move much, and thus will not affect predictions of solar demand, unless models for solar demand were based on worst case peak oil scenarios.

1.1.3 Is CIGS Ready for High Volume Manufacturing?

It is beginning to look like CIGS really is ready for high volume manufacturing. Global Solar now has a 40 MW capacity plant operating in Tucson Arizona and a 35 MW capacity plant coming on line in Berlin Germany. The Berlin plant has moved from one to two shifts per day and is planning to move to three shifts soon. The flexible BIPV roofing modules made by Global Solar are both International Electrotechnical Commission (IEC) and Underwriters Laboratories (UL) certified. Global Solar has recently announced multi-year, multi-megawatt agreements with ENERGYKA, ISCOM SPA, BA energy in Europe and Beachside Solar, Pfister Energy and Inovateus Solar in the US.

It is not surprising that CIGS is the last thin-film technology to be successful in high volume manufacturing. It is the newest of the thin-film technologies and by its nature as a quaternary alloy, has deposition conditions that are more challenging than those for either the two component CdTe technology or the doped silicon films in a-Si.

Another indication that CIGS is ready for high volume manufacturing is the entry of established high volume, technical manufacturing companies such as TSMC into the field. The entry of TSMC with its established record of efficient and cost effective high volume manufacturing bodes well for CIGS PV technology.

While start ups have advantages in agility, established technology firms such as TSMC have development and fan out to high volume manufacturing as core competencies. They also have a much higher probability of success for bringing new technologies such as CIGS into high volume production than many of the CIGS start ups that have stumbled in years past.

Semiconductor companies are especially well suited to thin-film solar, as they are very experienced in developing complex thin-film depositions.

Companies such as TSMC also have established relationships with the equipment suppliers, which also gives such firms an advantage over start ups. TSMC plans to have 1 GW of capacity for CIGS available in 3-5 years. It has committed $258 million on a facility in Taichung that will provide 100 MW of capacity by the end of 2012 and another 100 MW in 2013, with an additional 700 MW coming on line in the next 3-5 years.

1.1.4 Will Flexible CIGS Be an Advantage vs. Other PV Technologies?

Flexible modules will be a key advantage for CIGS, as they will be the only solar technology that will be able to provide a flexible module in the 15 to 20% efficiency range in high volume in the near future:

- While flexible a-Si modules are available, their efficiency is less than half that of CIGS and would thus require double the area to provide a given amount of power. The module efficiency question is important for flexible modules, because they will likely be used where less surface area is available compared to flat panel applications.

- Flexible applications are likely to be building integrated PV projects where flexible modules are necessary for covering complex shapes. They will also find use as integrated features in clothing or bags that provide recharging for battery-operated electronics. Here the higher efficiency of CIGS is crucial for providing modules for small electronics battery recharging applications in an acceptable form factor. Flexible CIGS cells will also have applications in military gear for recharging electronics in the field.

1.1.5 CIGS and BIPV: A Match Made for Rooftops?

Building integrated PV is one area where CIGS is predicted to gain appreciable market share as soon as it is available. Underlying this expectation are two key reasons:

- CIGS is the only technology that currently provides both high efficiency and a flexible form factor. High efficiency is crucial for BIPV, as the surface area of structures is limited and thus the highest efficiency possible is desirable for providing the required electrical needs.

- CIGS, when available in high volume at equivalent cost to c-Si, will gain market share quickly as it has the flexible advantage over c-Si and the efficiency advantage over a-Si. Dow's powerhouse CIGS-based shingle is now available in limited quantities. Current production is only 400 shingles per day, which is a long way from their goal of having

220 MW of capacity in place by 2015; however, they have certainly taken a step in the right direction for BIPV. The early production volume is going to a demonstration housing project in Arvada Colorado.

While BIPV is nearing production readiness, it is likely that the sovereign debt issues of Europe and the still stagnant US housing market will limit growth of new BIPV in these regions. There are, however, ample opportunities in the BRIC countries and other emerging markets to create significant demand for BIPV CIGS-based products.

1.1.6 CIGS' Achilles Heel: Lifetimes and Encapsulation

Lifetime and encapsulation are two factors that have slowed adoption of CIGS. These issues are now largely closed from a technology perspective, but remain open from a cost perspective:

- CIGS encapsulation is following much the same path as a-Si encapsulation, which encountered issues in the early 1980's as that technology was being developed.
- Because CIGS is much more moisture sensitive than a-Si, the techniques that proved viable for a-Si do not provide the long-term reliability needed for acceptable module lifetimes. Much like the experience with a-Si, where early reliability failures created a poor reputation that took several years to get beyond, early reliability failures of CIGS have created a similar situation today.

Rigid modules with glass encapsulation or glass with a metallic back and improved edge sealants now routinely pass all reliability testing. There is still work ongoing to put flexible encapsulation systems in place that can provide greater than 20-year lifetimes, but at a cost point that keeps the technology competitive. Current dyadic systems, which incorporate two or more alternating layers of polymer and thin ceramic, have shown promise but are expensive.

Firms such as Dow, Fujifilm, DuPont, and 3M are actively working to improve the available encapsulation solutions. While a lifetime of 20 years or more is a requirement for BIPV, a lower standard will be acceptable for cost-sensitive consumer products such as cell phone chargers and bags/clothing with integrated solar battery charging features.

1.2 Objectives and Scope of this Report

The purpose of this report is to examine the opportunities and challenges for the materials and markets for CIGS. The compositions referred to as "CIGS" in this report include not only copper indium gallium diselenide but also copper indium diselenide (CIS) and similar materials that substitute sulfur for some or all of the selenium.

While a thoughtful understanding of these materials and their markets necessarily requires an understanding of the underlying TFPV markets, the materials opportunities and not the module level opportunities are the major focus of this report. In covering the CIGS materials markets, this report includes each component of the cells and modules.

Substrates, active materials, electrode materials, buffer layers, encapsulation and antireflection materials are included in the report, but module circuitry, grid interconnects, and structural mounting materials and components are not. In covering TFPV materials, we also consider the form in which they are used, such as sputtering targets, gases, precursors, etc., and trends with respect to deposition methods of these materials.

While one of the major goals of the report is to provide detailed forecasts for markets of CIGS materials, the continued volatility and ambiguity of relevant worldwide economic data increases the uncertainty of such forecasts and predictions:

- For example, many of those who entered the turnkey a-Si manufacturing business or CIGS in 2007 based on high energy prices and easy credit and high polysilicon prices were driven from the field when credit unexpectedly tightened, energy prices collapsed and the polysilicon shortage came to an end.

- While some economic indicators point to a tepid but sustainable recovery in the U.S., continued worries about European and US debt dominate the economic news, resulting in worldwide growth estimates that are neither certain nor agreed upon in the economic community. Such a combination of conflicting economic data and uncertainties inevitably makes it challenging to reliably quantify the markets for CIGS materials.

The report is international in scope. The forecasts are worldwide and there has been no geographic selectivity in the firms covered or interviewed in the collection of information for this report

1.3 Methodology of this Report

Extensive interviews with various industry sources carried out in the fall and winter of 2011 are the primary sources of the opinions and conclusions in this report. Additionally, some of the data for this report comes from other NanoMarkets reports, including "*CIGS Photovoltaic Market Opportunities 2011,*" "*Thin-Film Photovoltaic Materials Markets 2011 and Beyond*," and "Building Integrated Photovoltaics Markets, 2011." Where information has been used from an earlier report, it has been reinvestigated, reanalyzed, and reconsidered in light of current developments and updated accordingly.

Secondary research for this report was also taken from information available on the World Wide Web, commercial and government databases, trade press articles, technical literature, information learned at technical conferences and trade shows, SEC filings and other corporate literature.

The forecasting approach taken in this report is explained in more detail in Chapter Four, but the basic approach taken here is to look at the underlying needs and markets, materials costs and capabilities, and the capabilities of key firms to productize CIGS-based materials and bring them to market, and assess the suitability and likely volume of CIGS PV and of each of the materials used in it over the next eight years.

The stated plans of the key firms are of course of special interest, although NanoMarkets critically considers these claims in light of all available data.

1.4 Plan of this Report

In Chapter Two, we review the materials, suppliers, and manufacturing technologies for CIGS and how they will impact volume and revenue growth. In Chapter Three we investigate markets for CIGS PV, including conventional modules and BIPV products. In this chapter we place an emphasis on identifying opportunities where CIGS is poised for growth compared to other PV technologies.

Finally, Chapter Four contains our eight-year forecasts for CIGS PV markets. We will quantify the markets for CIGS PV by manufacturing technology and product type, with estimates of demand for absorbers, transparent electrodes, reflectors, and anti-reflective materials.