Indium Markets for Photovoltaics

June 2009

Executive Summary

This report is one of a series of "Metals in PV" reports intended to fill a niche, targeting an audience interested in the covered metals as they relate to the photovoltaics industry. In the specific case of this report, the target audience is interested in indium as it is used in photovoltaics (PV). Such an audience would be interested in portions of the content of NanoMarkets' recent reports on ITO, CIGS PV, the other individual TFPV technologies, or on the range of materials used in TFPV. But even combining those reports would omit some valuable information relevant to indium's use in PV, and would include reams of information not directly relevant to the niche audience. This report, like the others in the series, offers an opportunity for the user to absorb NanoMarkets' extensive body of knowledge in the specific subject area of interest to the target audience, in a more concise format and with more comprehensive coverage than achieved by assembling multiple reports intended for broader audiences.

E.1 Overview of Indium Use in PV Manufacturing

The indium industry has grown rapidly in the past ten years or so, with indium production and consumption increasing exponentially. Only a small portion of indium consumption is currently used for the PV industry, but that portion is growing. The major force driving this increase in PV-related indium consumption is the growth of CIGS PV. Of the approximately 20 tons of indium currently consumed annually by the PV industry, more than half of it is used for the CIGS absorber layer of CIGS PV cells, even though they make up less than two percent of worldwide PV production in terms of megawatts. NanoMarkets expects CIGS' portion of PV-consumed indium to rise to over 80 percent by 2016, while CIGS PV cells will still represent only eight percent of PV megawatts.

The other uses of indium in PV are not as dramatic in quantity or growth. Indium-doped tin oxide (ITO) is used in many PV technologies—especially thin-film PV (TFPV) technologies—for transparent electrodes, and the volume of ITO consumed for this purpose will increase along with the rapid growth of TFPV. But the penetration of ITO as the transparent conductor in the TFPV market is not very high (about 30 percent) and it is declining as less-costly alternatives are being used more frequently. ITO accounts for about a third of indium consumption by the PV industry, and that will be reduced to about a sixth by 2016.

Indium phosphide (InP) PV, although it can consume very large quantities of indium per unit of cell area—especially if InP wafers are used—is not projected to grow very much over the forecast period, precisely because of its use of costly materials (including indium). While some InP PV cells may emerge from the lab, these will be for high-performance niche applications. Even the military and space niches use gallium arsenide (GaAs) PV cells in much greater proportion than InP cells for their high-performance applications. NanoMarkets expects InP PV to account for only about one percent of indium consumption in PV by 2016.

Overall, and driven by the growth of CIGS PV, NanoMarkets expects indium consumption by the PV industry to grow about ten-fold over the next eight years. This is faster than the growth in consumption expected by the display industry, which is the dominant user of indium, and PV will account for increasing proportions of worldwide indium consumption over the forecast period.

There are some who have been alarmed (at least before the current economic downturn) that the rapid growth in indium consumption will lead fairly quickly to widespread depletion of geologic resources, dwindling production, and indium prices in excess of $10,000 per kilogram. But this is not the view taken by indium industry insiders and NanoMarkets. Even considering only worldwide reserves that are currently economically extractable from zinc ores, there is plenty of indium for decades of increasing consumption. And this does not take into account the increases in extraction facilities and yields, extraction from other sources besides zinc ores, and recycling that would inevitably result from an extended shortage.

A more significant concern is the risk of short-term fluctuations in worldwide zinc demand—and the resultant fluctuations in zinc mining production—since indium is basically a by-product of zinc refining. Short-term supply and demand mismatches are also likely to happen since it takes six to eight months for new indium capacity to begin producing indium. Thus, NanoMarkets expects short-term price fluctuations to be routine for indium over the course of the forecast period, while the long-term price trend will be more slowly upward.

E.2 Key Developments and Trends in the Use of Indium in PV Manufacturing

The number one trend that relates to indium consumption in the PV industry has just been alluded to—the rapid growth of CIGS PV. CIGS PV will make up an increasing share of both TFPV and the overall PV market over the next eight years. This will drive up indium consumption by the PV industry, but there are also some important subtleties to this growth.

Currently, the indium for CIGS is usually deposited onto PV cells by vacuum deposition—sputtering or evaporation. These are very inefficient processes in terms of material usage, and only about 30 percent of the indium consumed makes it onto the substrate where it belongs. This means that 70 percent of the indium used can be considered "wasted," although much of it is recycled. For such a costly material as indium, this low deposition efficiency is a cause for concern.

Different methods of depositing the CIGS absorber layer have been under development and are currently in production by some manufacturers. These other methods—electrodeposition and printing with inks—are in part designed to achieve higher efficiencies of material deposition, but they are also intended to facilitate the CIGS PV manufacturing process in other ways. For instance, they can eliminate costly vacuum deposition equipment, increase throughput, or work better with roll-to-roll processing. Increasing use of these methods will decrease the amount of indium consumed per unit area of the cells, easing both production costs and demand for indium. We take these trends into account in the forecasts in Chapter Four.

Conversion to electrodeposition and printing of CIGS has another effect on the indium market for PV: the types of indium materials used will change according to the deposition method. Sputtering targets and evaporation slugs are used for vacuum deposition, and the relative consumption of these types of indium materials for the PV industry will decrease in favor of indium salts (including indium chloride and indium sulfamate) for electrodeposition and nanoparticles of indium, indium selenide, and indium oxide for incorporation into inks.

Another set of trends, which relate to ITO consumption in the PV industry, is also important. These trends will oppose each other in their effects on the volume of indium consumption by PV. First is the growth of TFPV overall (including CIGS and the other TFPV technologies). Since TFPV uses transparent conductors for its front electrodes (and sometimes also its back electrodes), while c-Si PV does not (with the exception of hybrid cells, which are discussed in the main body of this report), the growth of TFPV—in absolute terms and as a proportion of the total PV market—will result in a growing competitive market for ITO.

The opposing trend is that ITO does not compete very well in this market—its share has declined sharply over the last several years and continues to decline. The opposing nature of these two trends is most apparent in the OPV market. Since this technology is still emerging, its growth rate (in percentage terms) will be very large. OPV also currently has the highest penetration of ITO among the PV technologies, so this growth will bring proportionate growth in ITO—and indium—consumption. But OPV is also the PV technology that is most actively developing substitutes for ITO and other TCOs, driven by the organic electronics industry, in which it is included. NanoMarkets expects both of these trends to be evident in the volume of ITO and indium consumed by OPV over the forecast period: consumption will increase as OPV emerges into commercialization, but will then decrease as cost reductions and the fruits of alternative transparent conductor development drive substitution of the ITO. These trends will also happen among the other TFPV technologies, but not as visibly.

These trends will also impact the indium market for ITO used in PV in much the same way as we discussed with the CIGS PV market. Here, we expect changes in deposition methods. Sputtering is an inefficient method for depositing ITO, as it is for CIGS, and there is some development work taking place to apply ITO using nanoparticle inks, including in the PV arena. NanoMarkets doesn't expect this trend to be as large as it is for CIGS, but ITO nanoparticle inks will still allow more production with less indium to the extent that they are used. They will also shift some of the demand away from sputtering targets and toward nanoparticles for inks.

There are competing trends in the InP PV market as well. Overall, this market (even when combined with other, higher-volume technologies like GaAs PV) is very small in proportion to the other PV technologies. But it uses more indium per unit of cell area than even CIGS, mainly because InP wafers are sometimes used (although epitaxial InP layers, applied to a wafer substrate of a different material, are more often used). While ITO and CIGS films are measured in single microns or even hundreds or tens of nanometers, InP wafers are in the hundreds of microns. This makes them—and the PV cells that use them—exceedingly expensive and NanoMarkets expects InP PV to remain a tiny fraction of the PV market throughout the next eight years.

But there will be some growth. Some InP PV cells are likely to make it out of the lab and into production, with modest increases in volume. But the competing trend here is the use of thinner and thinner wafers of InP. NanoMarkets expects InP wafer thickness to decrease by about half over the next eight years, and this will probably outweigh the modest gains in volume, bringing down indium consumption by InP PV.

The indium market impacts the PV market as well. With the onset of the current economic recession, demand for the flat-panel displays that dominate the ITO (and indium) market has dropped substantially and indium prices have come down with it. This will have the effect of slowing the trend of substituting alternative transparent conductors for ITO in PV as well as in other ITO markets. The price of indium is also important to the (eventual) ramp-up of CIGS PV to truly high volumes. In a marketplace where competition is largely based on cost, indium prices will have an impact on CIGS PV's competitive position.

E.3 Opportunities for Mining, Refining, and Distribution Firms

While the PV industry is currently only a small part of the indium industry, it is growing rapidly as a proportion of the overall indium market, especially CIGS PV. This in itself is something to keep in mind, as indium for CIGS PV will become about 10 percent of the indium market within the eight-year period covered by this report. Beyond being prepared for this growth, it will be important to develop relationships with the PV manufacturers and the firms that produce intermediate products for them, to help ensure efficient supply and distribution.

There are other opportunities for mining, refining, and distribution firms as well. Indium firms should be prepared for changes in the mix of indium products demanded by the PV industry. The greater proportion of CIGS among indium-containing materials has already been mentioned, but intermediate products—for both ITO and CIGS—will also shift somewhat away from sputtering targets and evaporation slugs, toward other materials like nanoparticles for ink formulations and indium salts for electrodeposition baths.

E.4 Opportunities for Indium-Based Materials Firms

Some of the same considerations for raw indium-producing firms are also opportunities for the firms that produce indium-containing materials for PV (and they are often the same firms). Relationships with the PV producers—especially CIGS PV—will be important to maintain efficient supply and to develop new and custom materials for young and still-developing technologies.

The trends in the PV industry point toward two shifts in indium-containing materials for PV: materials for CIGS PV will account for a growing proportion of volume, and materials will include greater proportions of inks for printing and salts for electrodeposition. CIGS is a newer material than ITO, and some development in the area of compositions and deposition processes is likely to continue. To an even greater extent, the electrodeposition and printing processes (including printing of ITO) are very new and the development of these processes and the materials used is nowhere near complete.

E.5 Opportunities for Solar Panel Firms

As has been mentioned in discussion of the opportunities for other kinds of firms, building relationships among different types of firms is an important opportunity for PV device manufacturers. Many opportunities for developments and improvements in processes and materials may be found through these collaborations. PV is very sensitive to both cost and performance, and in many cases performance of cells produced by high-volume manufacturing is significantly below that of lab-produced cells. A better understanding of the materials may improve performance and lead to modifications of the materials used.

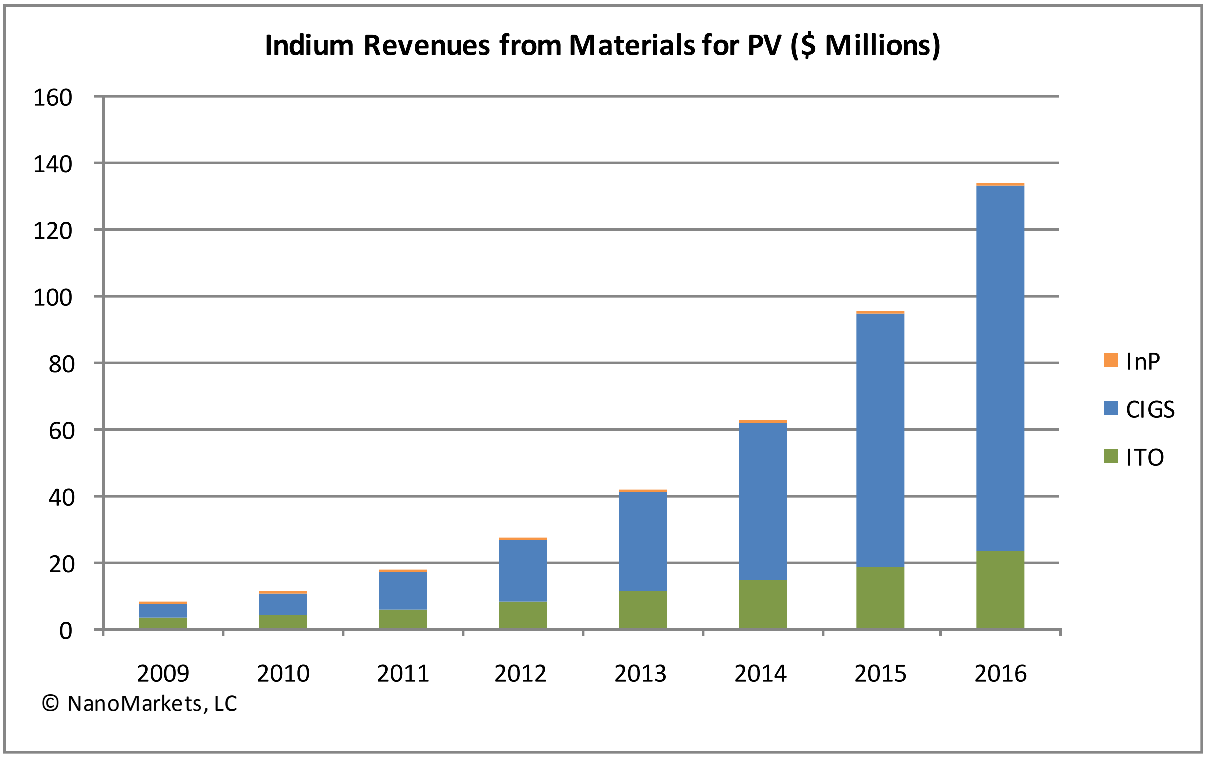
The relatively low current price of indium can yield some opportunities for CIGS PV firms in particular, for instance with supply agreements, in addition to lower current costs. It is acknowledged that these kinds of opportunities will be difficult to pursue in this economic environment because of the reduced PV demand and the shortage of the venture capital that is needed at this point in CIGS PV's development.

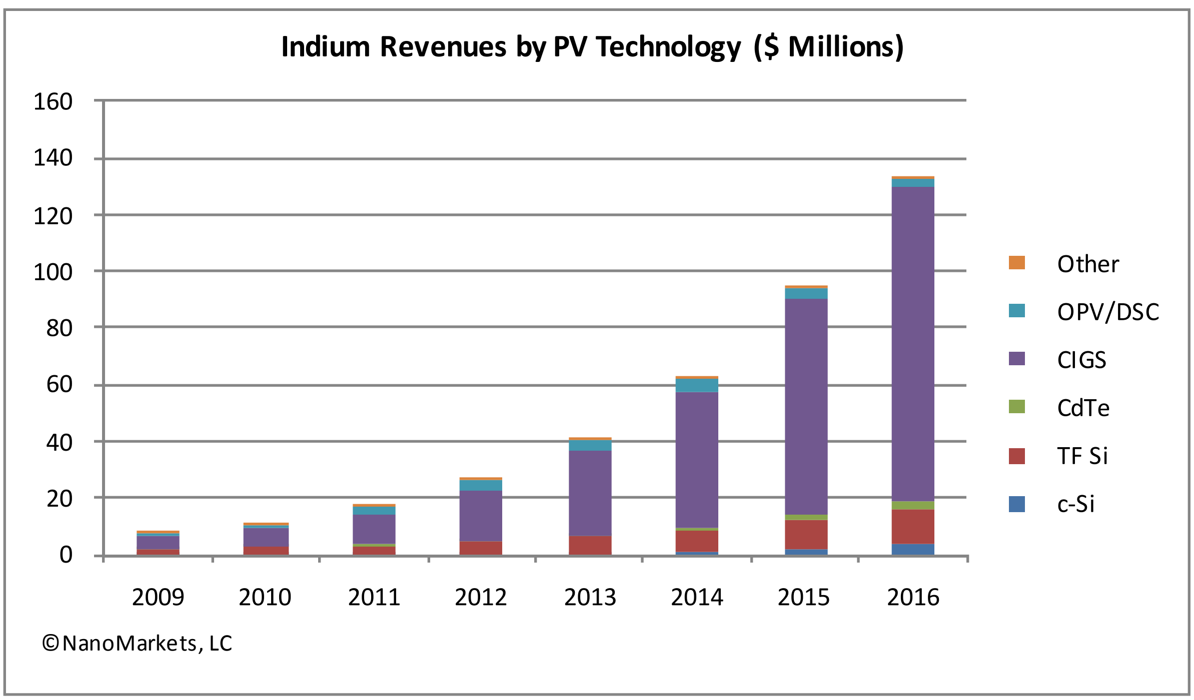
E.6 Summary of Eight-Year Forecasts

The growth of the PV industry has been very impressive over the last several years, driven by high and rising fossil fuel prices and growing concern about their geographical and political distribution and the environmental effects of extracting and burning them. The growth of TFPV within the PV market has been even more impressive; it has been driven by the shortage and high price of silicon (consumed in large quantities per megawatt of conventional, c-Si PV) and its lighter weight and potential flexibility, in addition to the factors driving PV growth overall.

NanoMarkets expects both of these trends to continue throughout the forecast period, although they will both be somewhat subdued for the next couple of years due to a number of factors resulting from the current economic recession. Fossil fuel prices are lower, construction starts are down, and concerns about the current state of the economy are diverting attention away from environmental concerns; these issues are slowing the growth of PV demand overall. Other issues—the end of the silicon shortage and a new shortage of start-up and venture capital funds—are slowing the growth of TFPV as a proportion of the overall PV market. But both growth trends are continuing even in the face of these challenges. As the economy improves in the mid to latter part of the forecast period, NanoMarkets expects these growth rates to pick up again as well.

This is a report on indium's role in the PV industry, and the relationship between the indium market and the various PV technologies is explored in depth in the main body. The implications for indium revenues generated by each of these technologies are summarized in Exhibit E-1.


Indium Revenues from Materials for PV ($ Millions)
160
140
120
100
80
60
40
20
0
2009
2010
2011
2012
2013
2014
2015
2016
InP
CIGS
ITO
© NanoMarkets, LC


Indium Revenues by PV Technology ($ Millions)
160
140
120
100
80
60
40
20
0
2009
2010
2011
2012
2013
2014
2015
2016
Other
OPV/DSC
CIGS
CdTe
TF Si
c-Si
©NanoMarkets, LC

After CIGS PV, the largest consumer of indium within the PV industry is TF Si PV, due to its high volume of production and fairly high penetration of ITO as the material for its transparent electrodes. Use of ITO by c-Si PV will increase as the proportion of hybrid cells, which have amorphous silicon on top of the crystalline silicon wafer and thus use similar front electrodes (including ITO).

For additional information about this and other NanoMarkets' reports, please contact us at (804) 360-2967 or via email at sales@nanomarkets.net or visit us at www.nanomarkets.net.