Venture Capital Investment into Thin Film Solar Photovoltaics – Where is it Going and Why?

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ABSTRACT

The large-scale adoption of solar photovoltaics (PV) depends largely on its ability to deliver electric power at a cost per watt comparable to that of conventional energy sources, and being able to do so with high conversion efficiencies. Among the different solar PV technologies, thin film PV technologies stand out as candidates likely to achieve these two objectives in the near term. We compare the three promising thin film PV technologies—amorphous silicon, cadmium telluride, and copper indium gallium selenium—in terms of cost per watt and conversion efficiency, and against the total venture capital investment flowing into each. The authors conclude venture capital investment seems to be guided by the prospect of high conversion efficiency more than low cost per watt, and offer possible explanations.

I. Introduction

The solar PV industry is poised for a period of tremendous growth.[1] Although the cost of delivering a unit of electric power, cost per watt, is currently higher for PV modules when compared with conventional energy sources, innovations in PV technology are expected to drive PV

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1 Steve O'Rourke et al., DEUTSCHE BANK, SOLAR PHOTOVOLTAICS (2008).

to cost parity with conventional energy sources in the coming years. In addition to cost, another important consideration is the amount of electric power that can be generated from a given amount of incident sunlight, called the conversion efficiency. This is an important consideration for large-scale adoption because high conversion efficiency means that the solar cell itself will be of a small physical size, an important consideration for many applications of solar PV.[2]

The currently popular technology, crystalline silicon (c-Si) has high conversion efficiency, but a high cost per watt because the component material is expensive. A group of new technologies, collectively labeled thin film technologies, offer much lower cost per watt primarily because they use less expensive materials than crystalline silicon. Although thin film technologies currently have lower efficiencies when compared to c-Si, new innovations to these technologies are expected to increase the efficiency. Thin film solar panels have the additional advantage that they can be made with flexible substrate materials like plastics, which makes it easy for them to be integrated into windows and roofs, an important consideration for successful commercialization of solar PV cells.[3]

Hence these technologies have generated considerable interest in the solar industry. Thin film solar grew from 5.9% to 8.6% of worldwide solar-electric equipment production in 2006 alone, and is expected to grow to approximately 20% of the market share by 2010.[4]

The leading thin film technologies in efficiency and cost per watt are amorphous silicon (a-Si), cadmium telluride (CdTe), and copper indium gallium selenium (CIGS). This article explores which of these three candidates is most likely to garner most of the solar photovoltaic market.

II. Methodology

To make a prediction as to which thin film technology will dominate the market, the following factors are considered. We take a first stab at this question by comparing the efficiencies and cost per watt of each technology. We then look at the flow of venture capital (VC) investment into these three technologies.

Venture capitalists should have full knowledge of the relative merits and therefore, for the sake of discussion, we try to explain their predictions on the possibility of success of these technologies, especially market success.

The time period of our study is January 2004 through December 2008.

III. Data

The data for this paper was obtained from National Renewable Energy Laboratory (NREL) press releases and reports, solar industry analysis and forecasts from Deutsch Bank, and academic journals including *Solar Energy Materials & Solar Cells* and *Progress in Photovoltaics: Research and Applications*. We summarize the data in the following graphs.

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2 S. R. Wenham et al., *Low Cost Photovoltaic Roof Tile*, 47 SOLAR ENERGY MATERIALS & SOLAR CELLS 325 (1997).

3 S. Hegedus, *Thin Film Solar Modules: The Low Cost, High Throughput and Versatile Alternative to Si Wafers*, 14(5) PROGRESS IN PHOTOVOLTAICS: RESEARCH AND APPLICATIONS 393 (2006).

4 O'Rourke, *supra* note 1.

Figure 1: CIGS Consistently Has Had the Best Research Cell Efficiencies.

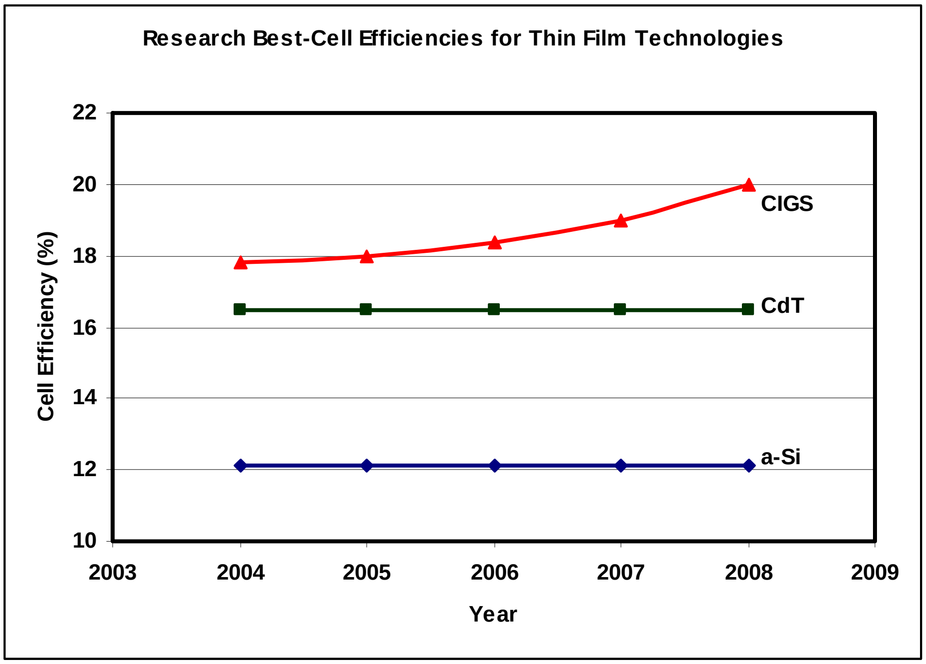

Figure 1 shows the best research cell conversion efficiencies for the three technologies, verified by NREL.[5] Cell efficiencies have not improved for CdTe and a-Si technologies since 2004 whereas they have consistently increased each year for CIGS. The cell efficiency of CIGS at the end of 2008 was 20%, ahead of the 16% achieved by CdTe.

Comparing discrete cell efficiencies alone, however, does not provide a complete picture because for commercial applications solar cells are rarely used individually. Many solar cells are put together in a module that can generate the appropriate voltages and currents needed for different applications. The conversion efficiency of the modules can be different from those of individual cells.

[5] Larry Kazmerski et al., NATIONAL RENEWABLE ENERGY LABORATORY, BEST RESEARCH-CELL EFFICIENCIES (2009).

Figure 2: CIGS Consistently Has Had the Highest Module Efficiencies.

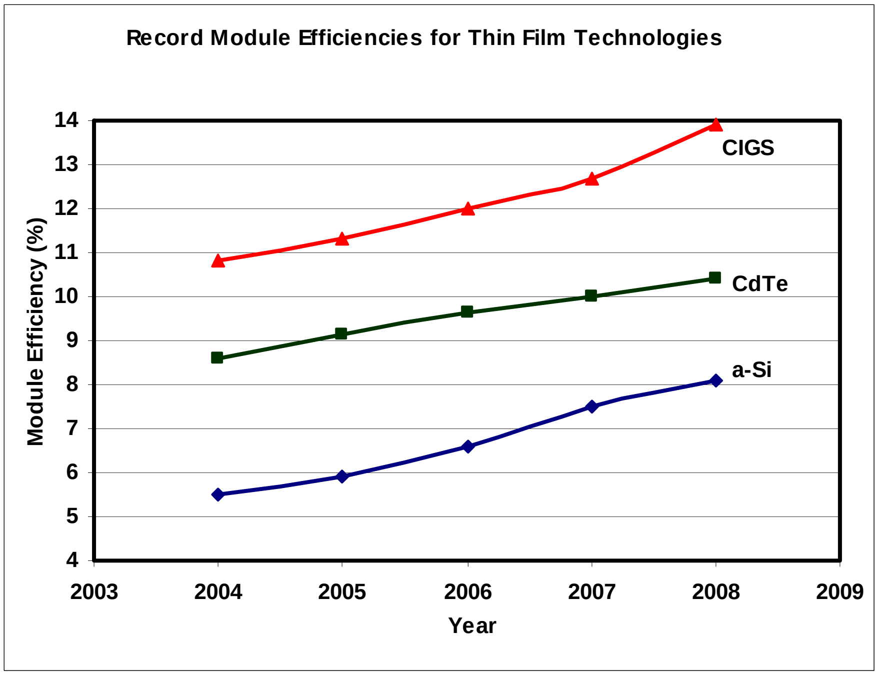

Figure 2 shows the module efficiencies for the three technologies.[6] Note that CIGS has consistently had higher module efficiency than both a-Si and CdTe for all years in 2004-2008.

[6] Martin A. Green et al., *Solar Cell Efficiency Tables (version 30),* 15(5) PROGRESS IN PHOTOVOLTAICS: RESEARCH AND APPLICATIONS 425 (2007).

Figure 3: VC Investment into CIGS Is Very High When Compared to CdTe and a-Si.

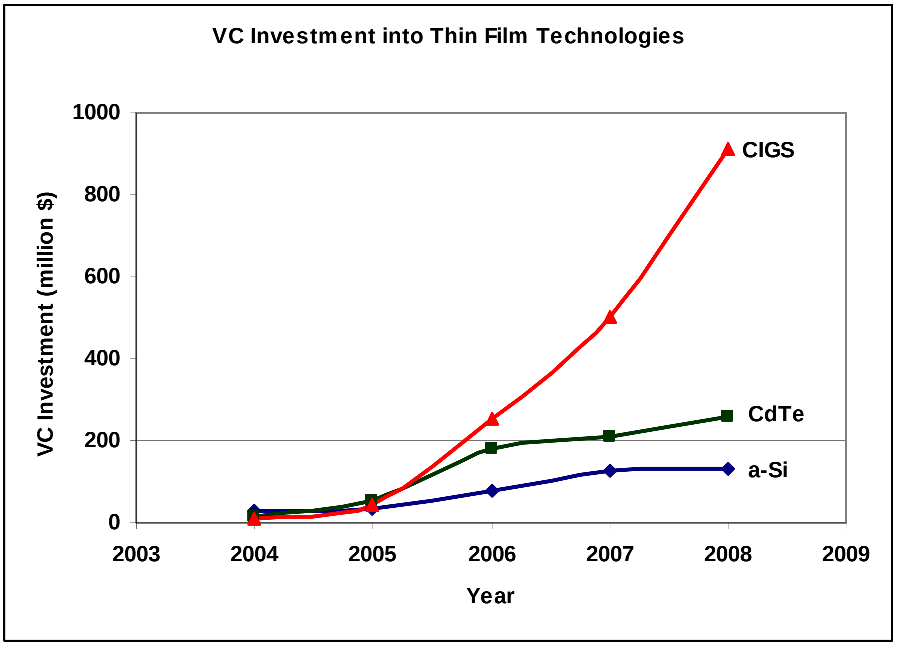

Figure 3 shows the VC investment in the three technologies. As is clear from the graph, VCs favor CIGS as the technology of choice—investment into CIGS far outruns even the combined investment into CdTe and a-Si.

IV. Discussion

It is clear from investment levels that VCs view CIGS as the most promising technology. The VC investment into CIGS in 2008 is more than the combined investment into a-Si and CdTe. This is despite the cost per watt for CdTe being lower than that of CIGS. The cost per watt for CIGS is $2.00, much higher than the $0.98 for CdTe or $1.65 for a-Si.[7] Notwithstanding being the more expensive technology currently, and being expected to remain so in the future, VCs favor investing in CIGS more than in the other two technologies. One explanation for this behavior is that continuing improvements in efficiency of CIGS cells would by itself lower the cost per watt and make CIGS cost competitive with CdTe and a-Si in the near future. However, there is no clear consensus on this and many studies of thin film photovoltaic technologies project that CIGS will remain the more expensive technology even as far as 2020.[8] An alternative explanation is that VCs view efficiency as the more important factor in determining the technology's success, even more than cost per watt. As Figures 2 and 3 show, the efficiency of CIGS is currently higher than CdTe and a-Si, both at the cell and the module level.

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[7] O'Rourke, *supra* note 1.

[8] *Id.*

If efficiency considerations are indeed the reason that CIGS receives the greatest financing, it raises the question of why do venture capitalists think higher efficiencies are more important than lower cost per watt? We offer some tentative explanations here. First, a higher efficiency means that the solar cell can be of a smaller size. Smaller size gives two advantages—the solar cell occupies less space in the house, whether on the roofs or the windows, and the cell will be lighter. This makes it easier for the solar module to be supported by most common residential and commercial roofs.[9] A heavy cell will need additional expensive roof work to be done to be able to support it. Second, it could be that VCs expect the cost per watt of CIGS to come down more than is currently expected. There are huge economies of scale in the solar cell industry.[10] The high cost per watt of CIGS might come down significantly when the economies of scale kick in as more production is done with CIGS technology. If CIGS does achieve comparable cost per watt to CdTe, it is likely that the higher efficiency of CIGS will push it forward as the dominant technology.

Could there be reasons other than high efficiencies why VCs are favoring CIGS? The choice of VCs may perhaps be simply indicative of the preferences of private equity investors. The highest amount of private equity investment in thin films has gone into CdTe, most likely because it is an established technology and has been proven in production on a large scale. CIGS, on the other hand does not have much current production, as shown in Figure 4. With most of the private equity investors directing their investments towards the more established CdTe technology, CIGS companies would find it difficult to attract private equity investment. The remaining option available for financing for CIGS firms is through VCs, and that might explain the huge VC investments in CIGS relative to CdTe and a-Si.

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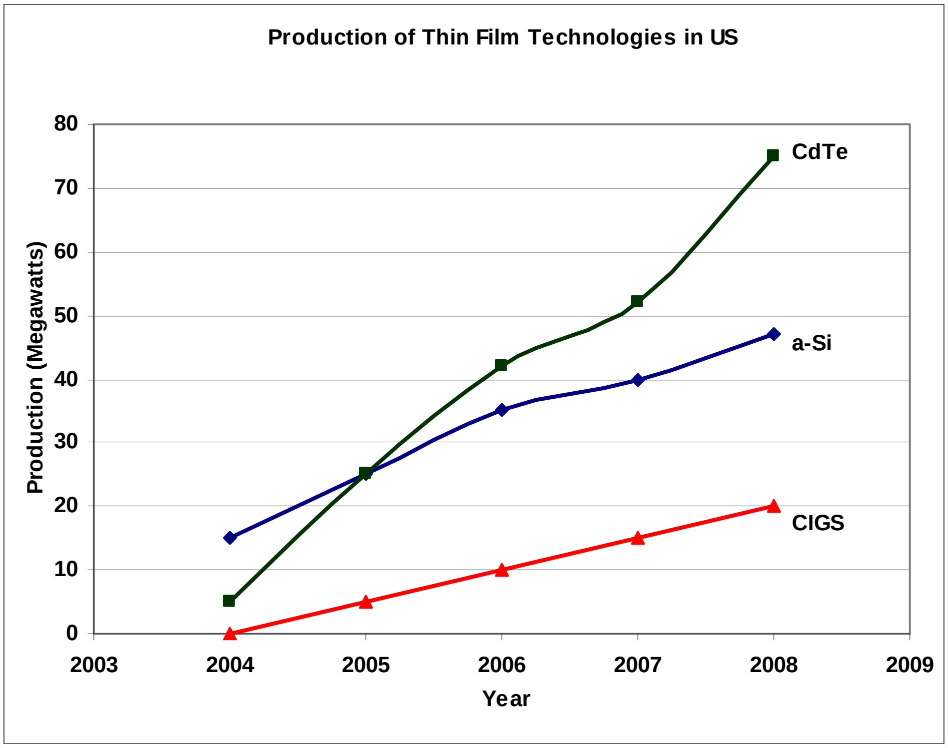
9 Wenham, supra note 2.

10 O'Rourke, *supra* note 1.

Figure 4: Most Current Production Uses Are CdTe or a-Si.



The above analysis also points to a potential adverse impact of the government policy of offering per unit subsidies to solar technologies. Although VCs seem to think that CIGS has the best long term potential, the government policy of offering per unit subsidies implies that most of the current government investment is going into CdTe and a-Si as they are currently the most available technologies. This points to a need to focus government investment into solar energy based on future potential as opposed to current dominance.

V. Conclusion

Among the three thin film solar technologies, VC investment into CIGS far outweighs those into CdTe and a-Si. This is despite the fact that CdTe offers the lowest cost per watt and is projected to do so for many more years. VC choices might be guided by conversion efficiency, since CIGS offers the highest conversion efficiency among the three and is projected to remain so. The choice of VCs points to a potential contrary implication of current government policy. Since a main form of government support into solar industry is using per unit subsidies, the bulk of the government support is garnered by CdTe and a-Si firms, which currently occupy a much larger share of the solar PV market than CIGS. If VCs are making the most lucrative choices, then it implies that the government is favoring technologies that are currently superior, over technologies that have a better prospect over the longer term.