Rise of thin-film technologies

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ABSTRACT

Until the year 2002, wafer-based crystalline silicon solar cells were almost exclusively the solar cell technology used for large-scale power plants. Since then, steady growth in the market share for thin-film technologies has been observed, although crystalline silicon technology still remains the most important solar cell technology used in large-scale PV power plants. The market share of thin-film modules, especially CdTe modules, has been continuously increasing in recent years, most notably in the German market. However, other countries like Spain, the USA, Italy and France have seen some large-scale CdTe-based modules being installed in power plants recently.

Introduction

Crystalline silicon wafer-based modules are the most commonly used type of modules and are suitable for almost any application. Their advantage – a low area requirement in comparison to other technologies – is the main reason for crystalline modules being so well suited to tracking applications. Use of thin-film technologies is in most cases limited to fixed, ground-mounted or roof-mounted power plants. An estimated annual installed power capacity sorted by technology [1] for the period from 2000 to 2008 is presented in Table 1. Before the year 2000, nearly all installed power capacity was based on c-Si modules. The market share of thin-film modules has been continuously increasing in recent years; this is most notable in the German market (Fig. 1) where CdTe solar modules have reached up to 50% of market share in some states (Fig. 3). Some other countries – Spain, the USA, Italy, the Czech Republic, France and Thailand – have seen the construction of several large-scale power plants based on thin-film technologies in the past year.

The technologies discussed in this paper are divided into the following groups:

- Silicon (wafer-based) crystalline modules (c-Si), which include polycrystalline and monocrystalline Si modules;
- Other silicon crystalline modules, which include thin-film crystalline modules and microcrystalline modules (μc-Si);
- Amorphous silicon modules (a-Si), which include single-junction and multi-junction amorphous silicon modules (this group also includes a-Si modules on flexible substrates);
- Cadmium telluride modules, which include modules based on CdTe;
- Other modules, including CIS/CIGS modules, concentrator modules, etc.

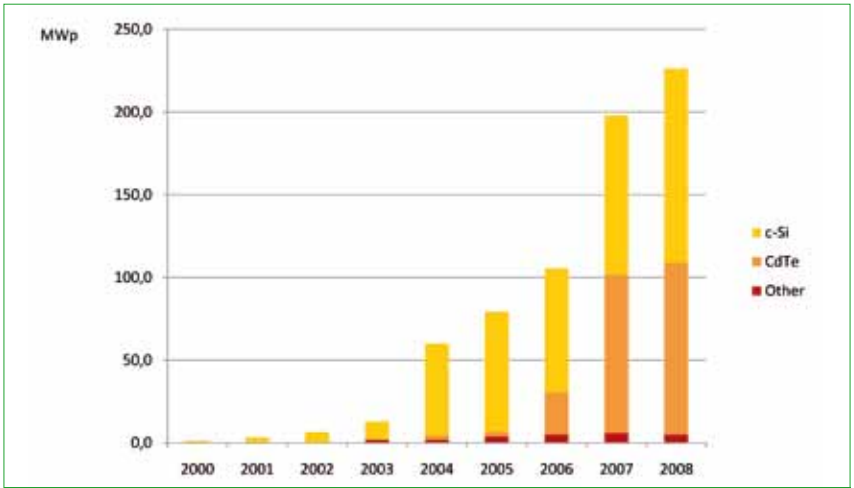

Figure 1. Estimated market shares of different technologies related to large-scale PV installations in the period from 2000 to 2008 (Germany) [1].

> "Statistical data on technology market share related to large-scale PV power plants can be interpolated with a high degree of accuracy."

Market share

The combined market share of CdTe and a-Si modules is estimated to be close to 10% where CdTe represents more than 7% and a-Si about 2.5% of the market share related to large-scale PV plant installations. The estimated market share of solar cell technologies is based on available data (the technology used) from about 1,100 large-scale PV power plants [1], which is very reliable at least considering large-scale PV installations. The amount of information from these samples represents a relatively large part of large-scale photovoltaic power plants, so statistical data on technology market share related to large-scale PV power plants can be interpolated with a high degree of accuracy. The majority of solar power plants put into service in the year 2008 were based on crystalline silicon solar cells (modules). Other commonly installed technologies include a-Si, CdTe, μc-Si and copper indium selenide (CIS or CIGS) modules.

	2000	2001	2002	2003	2004	2005	2006	2007	2008
c-Si	5.2	9.5	19.6	25.9	77.6	103	155	453	2364
a-Si				3.2	1.9	4.8	10	12	>45
CdTe					3.0	3.2	29	110	190
Other						<1	<1	<20	<5

Table 1. Solar module technologies: estimated annual installed power capacity (MWp) in the period from 2000 to 2008 related to large-scale PV power plants (>200kWp) [1].

MWp	Country	Location	Description	System integrator
40	Germany	Brandis	Ground mounted, 550,000 CdTe modules	juwi
14.75	Germany	Köthen	Ground mounted, 200,000 CdTe modules	juwi
11.8	Spain	Zaragoza	Roof mounted, 85,500 a-Si modules	Veolia Environment
10	USA	Boulder City, NV	Ground mounted, 167,000 CdTe modules	First Solar
10	Germany	Helmeringen	Ground mounted, 135,000 CdTe modules	Gehrlicher Solar
8.5	Germany	Eckolstädt	Ground mounted, 115,000 CdTe modules	Beck Energy
8.4	Germany	Trier	Ground mounted, 112,500 CdTe modules	Conergy
7	France	La Narbonnaise	Ground mounted, 95,000 CdTe modules	EDF
5.9	Spain	Darro Granada	Ground mounted, 80,000 CdTe modules	Beck Energy
5.8	Germany	Igling-Buchloe	Ground mounted, 78,000 CdTe modules	Conergy/Epuron
5.6	Germany	Wörrstadt	Ground mounted, 76,800 CdTe modules	juwi
5.3	Spain	Villanueva de la Jara	Ground mounted, 75,500 CdTe modules	Phoenix Solar
5.3	Spain	San Clemente	Ground mounted, 75,500 CdTe modules	Phoenix Solar

Table 2. Some of the largest thin-film technology-based PV power plants constructed in 2008 [1].

Installed power capacity of other module types like Si microcrystalline modules or CIS/CIGS modules for example is low in comparison to other technologies – estimated to be less than 1%. A significant increase of market share was observed for other thin-film technologies like a-Si; however, while the market share of these technologies remains low in comparison with c-Si, 2008 saw much more power capacity being installed than ever before. The first large-scale power plants with thin-film arrays were constructed in 2003; with close to 3MW of power capacity, their market share was about 10%. Following the decrease of installed power capacity of large-scale power plants a year later, thin film's market share since 2005 has increased continuously.

It is estimated that – considering large-scale PV power plants – in 2008, about 50MW of power capacity was installed with a-Si and more than 190MW using CdTe technology (Table 1). The market share of CdTe modules increased in 2004, reaching about 10% two years later and increasing again to more than 15% in 2007. Because of a significant increase in the power capacity of c-Si installed in 2008, growth in the sector dropped to less than 10% in 2008. Nevertheless, it retains a firm hold on a large portion of market share for some regions (Fig. 2) and applications [2].

In Germany, market share of CdTe modules increased significantly in the last three years. CdTe modules represented a market share of about 25% in 2006, a figure that has jumped by up to 50% in the past two years. Due to competitive pricing, CdTe modules were used for several of the largest ground-mounted power plants [2] in Germany (Table 2); consequently such a large market share is not a surprise. An increase of CdTe market share was also observed in 2008 in other countries such as Spain, the USA and France.

Similar market share increases related to thin-film technologies have been observed in the Czech Republic and in Thailand, with a-Si remaining the dominant thin-film technology of choice in these countries.

Ground- and roof-mounted power plants

Thin-film modules are almost exclusively

Courtesy of Suravia

Figure 2. The Villanueva de la Jara PV power plant, Cuenca, Spain, consists of c-Si and CdTe modules, constructed by Phoenix Solar in 2008.

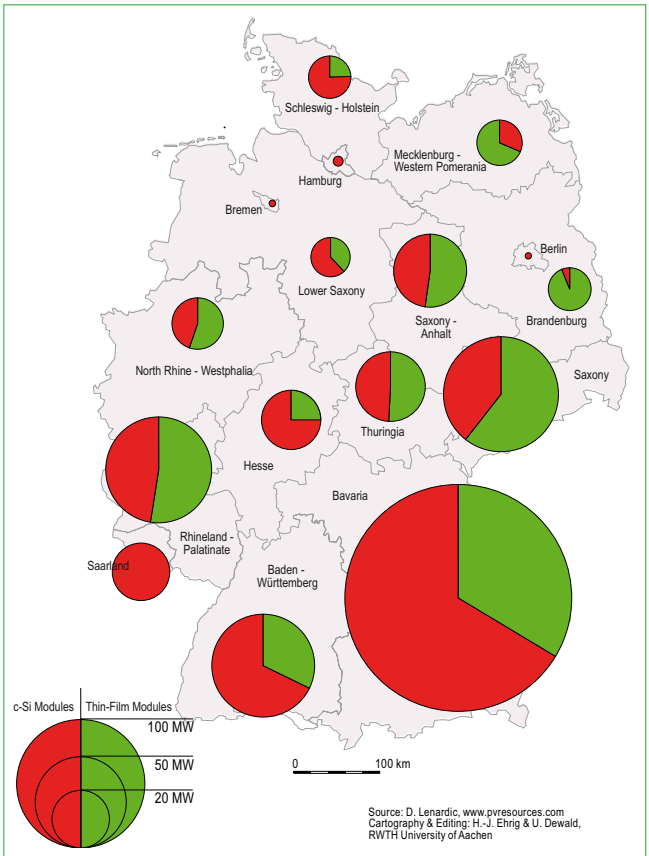

Figure 3. Estimated market shares of different technologies in German states as at December 2008 related to large-scale PV installations [1].

the technology of choice for use in fixed mounted arrays. Compared to 2007, last year saw about fourfold power capacity increase of a-Si and twofold power capacity increase of CdTe (Table 1). The most important markets for thin-film technologies are Germany, Spain and the Czech Republic. Meanwhile, CdTe has the largest market share among thin-film material in Germany (Fig. 1) and Spain, while in the Czech Republic (with about 20% of market share) a-Si is the dominant thin-film technology.

While several of the PV technology types can be used for roof-mounted power plants, crystalline silicon is the most common material used, although a-Si or CdTe are also used quite often. The market share of thin-film technologies – primarily a-Si and CdTe – has continuously increased since 2004, as shown in Table 3. Almost 25% of all large-scale roof-mounted power plants constructed in 2008 consist of thin-film modules. More than 20MW of large-scale roof-mounted PV plants were constructed using a-Si modules, with a slightly lower uptake of CdTe modules.

The past year not only showed the largest cumulative power capacity installed, but it also saw thin-film technologies take the highest market share. Owing to their list of advantages, thin-film technologies have a bright future. Market share will remain healthy, regardless of whether or not the technologies in use are based on silicon. One of the main concerns associated with all thin-film technologies is recycling. Developing and defining independent programmes for recycling modules and other components of photovoltaic systems are seeing intense

	2004	2005	2006	2007	2008
c-Si	29.1	51.2	59.1	62.8	109.3
CdTe	<1	<1	3.7	14.0	18.6
Other	<0.5	0.5	6.0	19.6	41.4

Table 3. Estimated annual installed power capacity (MWp) of roof-mounted PV power plants by technology type [1].

Courtesy of HiTech Solar

Figure 4. Ostrožská Lhota PV power plant was constructed in 2008 using c-Si modules. Ostrožská Lhota is one of the largest PV power plants in the Czech Republic, a country that has seen huge growth in recent months [4].

activity [3], and look set to represent one of the industry's main assignments in the coming years. Recycling cannot and should not be left to individual producers, but rather needs to be managed systemically and integrally, regardless of module type, technology, and manufacturer.

The data that represent the basis of this report is published at http://www.pvresources.com/en/top50pv.php and is available free of charge.

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Denis Lenardič holds a degree in electrical engineering from the University of Ljubljana, Slovenia. From 2004 to 2008 he served as chairman of the Slovene national section of IEC »TC82« Technical Committee, and has been systematically collecting data about large-scale photovoltaic power plants for several years.

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