

1.0 INTRODUCTION

This assessment of the polysilicon market provides a review and analysis of the manufacturers of polysilicon and their two main industry customers, the traditional semiconductor industry and the growing photovoltaic industry. It provides strategic planning information with a comprehensive picture of the current market situation, and substantial background on all three industrial groups. With an understanding of the development, capacity and future of these three industries, and an analysis of the current business environment, a likely market scenario is used to provide a five-year forecast in the final chapter.

1.1 CHAPTER SUMMARIES

Chapter 1- Introduction – Provides a brief description of each of the various chapters of the report. The report methodology is then discussed followed by an executive summary with a summary of the market environment and key findings.

Chapter 2 – Polysilicon Manufacturers – Provides a detailed description of each of the traditional polysilicon producers. This presentation is followed by a discussion of the expansion plans of the traditional suppliers. The chapter closes with a discussion of the new entrants into the production of polysilicon. The discussion includes both those new entrants employing traditional technologies and those planning to use new technology.

Chapter 3 – Semiconductor Industry Polysilicon Users – Discusses drivers for demand in the semiconductor industry. A brief discussion of the electronic industry is followed by the generation of semiconductor demand drivers. The producers of silicon wafers, the consumers of polysilicon, and the providers of polysilicon are analyzed on a company by company basis. The chapter concludes with a semiconductor buyer / seller matrix.

Chapter 4– Photovoltaic Industry Polysilicon Users – This chapter begins with a discussion of the current market factors affecting demand for photovoltaic cells and modules. It then discusses the growth in demand in world primary energy and electricity generation, providing an understanding of global and regional growth in each.

Photovoltaic growth scenarios are then compared to show the length of time required to achieve percentile shares of these conventional forms of energy growth. After a discussion of photovoltaic market segments, the chapter describes the progress of photovoltaic growth over the last 25 years and the driving factors increasing that growth. Developing market shares of PV technology are then reviewed, with the factors affecting the dominance of crystalline technology over the last quarter century. Major industry producers are summarized for crystalline silicon photovoltaic cells, with discussion of the large thin film producers.

Chapter 5 The chapter then describes the silicon wafer and silicon raw material suppliers for photovoltaic industry. After discussing all of the consumers and producers of photovoltaic ingots, wafers, and polysilicon, the chapter presents a silicon material flow chart for each of the major photovoltaic cell and silicon material suppliers. The chapter closes with a photovoltaic cell and wafer buyer / seller matrix and a wafer and polysilicon buyer / seller matrix.

Chapter 6 – Semiconductor Polysilicon Forecast – Describes a vertical integration chain starting at the top with GDP and following it through to the electronics and semiconductor industries to the silicon wafer and polysilicon level. Forecasts out to 2011 are presented for GDP, Electronic Systems, Integrated Circuits, and silicon materials needed by the semiconductor industry.

Chapter 7 – Photovoltaic Polysilicon Forecast – A discussion of the changing energy environment as it affects ongoing market development. Historic forecast scenarios and actual growth in the photovoltaic market provide a perspective on future market expansion and polysilicon demand. The history of photovoltaic consumption of polysilicon is used to forecast potential polysilicon demand, in combination with photovoltaic market projections.

Chapter 8 – Polysilicon Supply And Demand Forecast – Market forecasts of semiconductor and photovoltaic industries' product demand are combined to estimate a most likely scenario of polysilicon consumption volume, taking the near term polysilicon availability into consideration. The end of the silicon raw material shortfall is anticipated for the year 2011.

1.2 REPORT METHODOLOGY

This report is directed toward the planning needs of general management and senior planning and business development managers, as well as providing technical managers with an additional perspective on the industry's progress in technology.

The forecasts included represent a combination of quantitative and qualitative analyses. The authors' individual experiences, each of more than 20 years, are used in the analyses of market size, development of technology, capacity increases and economic effects. Quantitative information has been gathered over more than 20 years, using primary surveys and personal discussions with experienced personnel in the three involved industries. These are discussed in this report, and used to assess market direction and industry response to changes in the market

Additional quantitative inputs include world demographics which are used in estimating addressable markets, costs associated with various PV and semiconductor technologies, and their corresponding competitors, and the budgets of various national and world agencies.

1.3 EXECUTIVE SUMMARY

The polysilicon industry has supplied the semiconductor industry with ever-increasing purity material for over 40 years. While material quality and timely delivery have seldom been an issue, the profitability of the polysilicon industry has been questionable at best. Patterns have developed where the polysilicon price drops soon after the production plants are constructed and remain low until the semiconductor industry's long term cyclical growth drives polysilicon demand to the point where it outstrips polysilicon supply.

As the gap between the supply and demand curves narrows, the polysilicon price increases to the point where re-investment in the industry is viable. After each expansion the price drops to the point where there is no profitability left in the industry. This has happened three times in the polysilicon industry's history and the current scene is primed for a recurrence.



While the semiconductor industry has created a rather financially unhealthy supply chain, the photovoltaic industry by contrast has almost no supply chain. For 30 years the photovoltaic industry relied primarily on scrap silicon from the semiconductor silicon production chain. Fortunately for the photovoltaic industry, its new millennium growth spurt occurred at a time when the semiconductor polysilicon industry was in a period of vast overcapacity. Thus a plentiful low-price supply of polysilicon was available for the period ranging from the late 1990s to the year 2003.

The year 2004 brought an end to this era of cheap plentiful polysilicon. In that year semiconductor polysilicon demand increased 15% and photovoltaic polysilicon demand increased by 45%. These demand surges created a dynamic where demand outstripped supply. With the continuing polysilicon shortage of 2006, the two polysilicon demanding industries are left to compete for the available material. The winner of this struggle was the semiconductor industry which owns the production technology and owns (either outright or partially) many of the plants.

This scarcity has evidenced a basic flaw in the development strategy for photovoltaic development. The photovoltaic industry has no viable supply chain to date for the raw material that it has selected for accelerated growth. It basically has been lucky to be able to develop to its present stage without its own supply chain.

While the polysilicon scarcity continues the solutions to the problem are already underway. These solutions are three fold:

- Existing polysilicon producers have announced plans to invest \$ 5 billion to construct new production facilities over the next 5 years
- New companies employing technological variations of existing technology have announced investments of \$ 4.4 billion in new facilities over the next 5 years
- New companies employing new technologies have announced plans to invest \$1.1 billion over the next 5 years

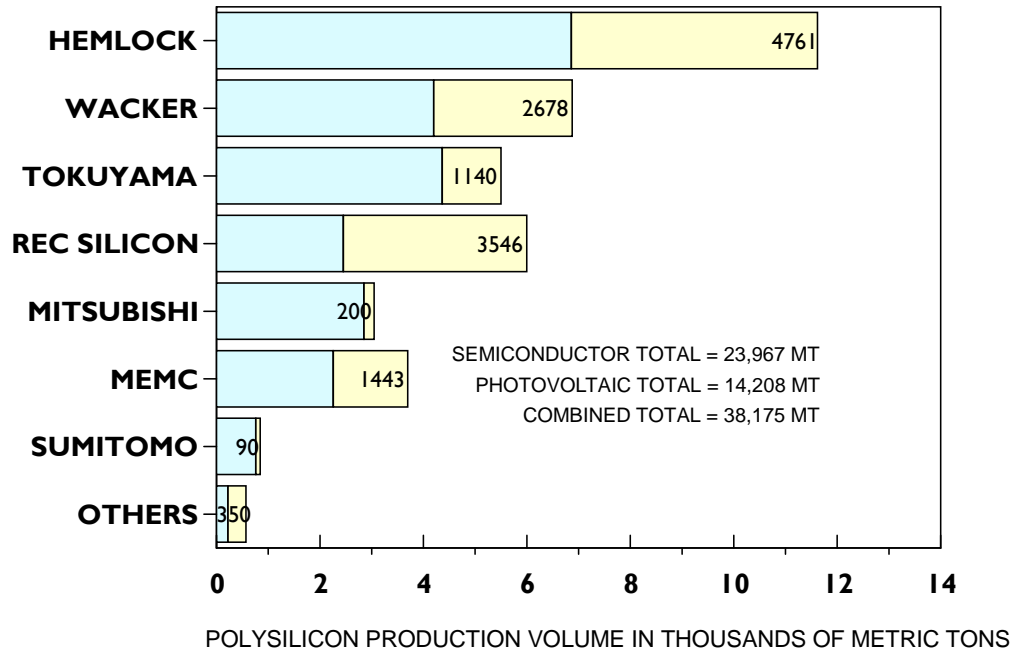
Given these dire conditions the photovoltaic and polysilicon companies have responded positively to ameliorate the effects of a tight polysilicon market. By operating their equipment in “solar mode” as opposed to the tradition “semiconductor mode” polysilicon manufacturers were able to increase their production from 31,400 metric tons to 38,085 metric tons. From the user side, the silicon per watt consumption rate decreased from 10.9 metric tons per megawatt (MT/MWp) to 9.77 metric tons per megawatt (MT/MWp). As a result the photovoltaic industry was able to grow from 1307 megawatts (MWp) to 1866 megawatts (MWp), an increase of 43%. The crystalline silicon portion of the market grew from 1226 megawatts (MWp) to 1697 megawatts (MWp), an increase of 38%.

In the near term the polysilicon industry will nearly meet combined semiconductor and photovoltaic demand at the volumes of the anticipated growth (42 % CAGR) Accelerated Scenario (2007 and 2010 time period). By 2011 the investments in polysilicon expansion should provide enough silicon raw material to meet the demand of even the most robust growth scenario (Energy Transition Scenario).

1.3.1 CURRENT POLYSILICON SUPPLY

The current supply of polysilicon is illustrated in Figure 1-1. The semiconductor supply in 2006 was 23,967 metric tons and the photovoltaic supply was 14,208 metric tons. Total polysilicon supply was 38,175 metric tons. In addition to the 14,208 metric tons of polysilicon, the photovoltaic industry also was supplied with 2454 metric tons of scrap silicon material for a total photovoltaic silicon raw material supply of 16572 metric tons. For the two industries together had a total silicon raw material supply of $(23,967 + 16,572) = 40,539$ metric tons.

FIGURE 1-1
2006 POLYSILICON SUPPLY
(in Metric Tons)



The largest polysilicon supplier is Hemlock Semiconductor. In 2006 Hemlock supplied 6860 metric tons to the semiconductor industry and 4761 metric tons to the photovoltaic industry for a total of 11,621 metric tons.

The position of 2nd largest polysilicon supplier was Wacker Chemie. In 2006 Wacker supplied 4201 metric tons to the semiconductor industry. Eighty four percent of this material was shipped to its sister company, Siltronic AG. In addition it supplied 2678 metric tons of polysilicon to the photovoltaic industry for a total of 6879 metric tons. The 3rd largest polysilicon supplier was REC Silicon. Its Butte, Montana, plant supplied 2454 metric tons to the semiconductor industry and 1246 metric tons to the photovoltaic industry. Its Moses Lake, Washington, plant supplied 2300 metric tons to the photovoltaic industry. The sales of these two plants together supplied 6000 metric tons in total and 3546 metric tons to the photovoltaic industry.

In 4th position is Tokuyama. Tokuyama supplied 4363 metric tons to the semiconductor industry and 1140 metric tons to the photovoltaic industry for a total of 5503 metric tons. Mitsubishi Materials also operates two polysilicon plants: one in Yokkaichi, Japan, and one in Theodore, Alabama. Both of these plants are primarily dedicated to the semiconductor industry. Similarly the Amagasaki plant of Sumitomo Titanium is dedicated to the production of polysilicon to the semiconductor industry.

The other plant produces polysilicon in a different form than the others. All of the above discussed plants produce rods of polysilicon, which are broken into chunks. The MEMC Pasadena plant produces granules of polysilicon. The only semiconductor user of these granules is MEMC. In addition to their captive use, a portion of these granules are sold to the photovoltaic industry. In total MEMC produced 3700 metric tons in 2006. Some 2257 metric tons were used internally to produce semiconductor wafers and 1443 metric tons were sold to the photovoltaic industry either as silicon ingot or as granules.

These existing producers announced have expansion plans:

- Hemlock 37,000 MT
- Wacker 21,500 MT
- REC Silicon 18,900 MT
- MEMC 15,000 MT
- Tokuyama 7,300 MT
- Mitsubishi 3,450 MT

1.3.2 KEY FINDINGS

- Crystalline based photovoltaic sales grew from 1226 MWp in 2005 to 1697 MWp in 2006, an increase of 38.4%.
- Photovoltaic silicon raw material demand increased from 13,363 metric tons in 2005 to 16,572 metric tons in 2006, an increase of 24.0 %.
- Semiconductor polysilicon demand increased from 19,942 metric tons in 2005 to 23,967 in 2006, an increase of 20%.
- In 2007, under the Accelerated Scenario (42%) for photovoltaics, the combined demand for polysilicon (46,707 metric tons) will outstrip polysilicon supply (44,085 metric tons), creating a deficit of 2,622 metric tons. At the Moderate Scenario growth of 32% the demand will be 44,958 metric tons reducing the deficit to 873 metric tons. To exceed these growth rates either the suppliers will have to squeeze some more supply out of their existing facilities or the photovoltaic industry will have to increase their silicon effectiveness beyond the anticipated reduction to 9.5 metric tons per megawatt (MT/MWp).
- Total photovoltaic polysilicon demand will be exceed the 25,770 metric tons per year semiconductor polysilicon demand by 2008, even under the slowest photovoltaic growth scenario (Moderate - 32%).
- Under the most likely photovoltaic growth scenario (Anticipated Scenario - 42%), the photovoltaic polysilicon demand of 58,409 metric tons will be double the 28,350 metric ton semiconductor polysilicon demand in 2010.
- In the year 2011, the polysilicon supply of 138,960 metric tons will be more than adequate meets the polysilicon demand of the various growth scenarios:
 - Moderate Scenario – 32% 82,971 MT
 - Anticipated Scenario - 42% 106,180 MT
 - Accelerated Scenario – 46% 119,222 MT

1.3.3 POLYSILICON SUPPLY AND DEMAND SUMMARY

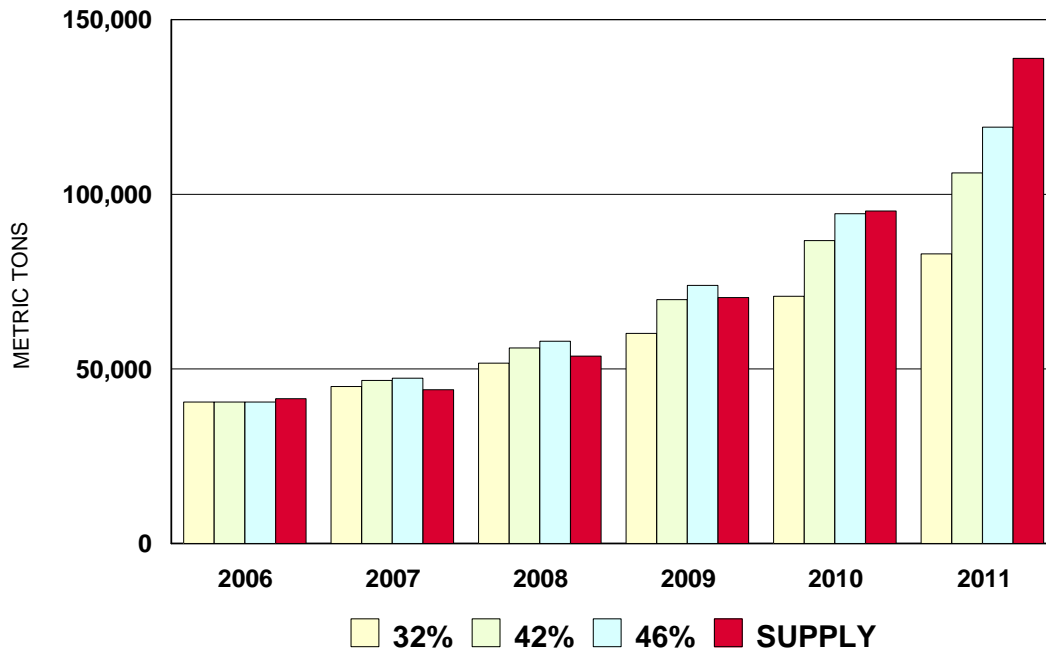
Polysilicon supply and polysilicon demand are plotted in Figure 1-2. In this figure the 3 different demand scenarios are presented for the years 2006 through 2011. In each group of bars the first 3 bars represent polysilicon demand growth under the following 3 different scenarios:

- 1) Moderate PV Growth Scenario of 32%
- 2) Anticipated PV Growth Scenario of 42%
- 3) Accelerated PV Growth Scenario of 46%

The 4th bar in the graph represents the anticipated polysilicon supply for the years 2006 through 2011. The injection of \$10.5 billion into the expansion of polysilicon supply is anticipated to increase supply at a 27.3% CAGR.

FIGURE 1-2

POLYSILICON SUPPLY VS DEMAND FORECAST



The red “supply” bar exceeds any of the demand bars in 2006, 2010, and 2011. In 2006 it barely exceeded supply. Supply was 41,847 metric tons and demand was 40,539 metric tons. In 2007 supply is anticipated to be below demand under all scenarios. Under the most likely photovoltaic growth scenario it is expected to be 2622 metric tons (5.9%) short. In 2008 the supply will exceed the Moderate Scenario growth demand, but again be short of the most likely Anticipated demand scenario by 2342 metric tons (4.3%). By 2009 the supply will be greater than either the Moderate or the Anticipated scenarios, but it falls short of the Accelerated Scenario demand by 3496 metric tons (4.9%). In 2010 the supply exceeds the demands of all 3 scenarios, but only exceeds the demand of the Accelerated scenario by 754 metric tons (less than 1%). By 2011 the supply exceeds all demand scenarios by a wide margin. It exceeds the Moderate growth scenario by 55,989 metric tons (40%), the Anticipated growth scenario by 32,780 metric tons (23.6%), and the Accelerated growth scenario by 19,000 metric tons (13.7%).

Under the 2011 conditions the excess supply will cause the price of polysilicon to fall to a few percentage points above the manufacturing cost. The excess of polysilicon material will lead to a differentiation in the price between the various grades of silicon raw material. The semiconductor grade price should exceed the photovoltaic grade price by 20% and the photovoltaic grade price should exceed the upgraded metallurgical silicon price. The amount will depend on the quality of the metallurgical silicon material. Again if the quality of the metallurgical silicon is high it will exceed the silicon scrap price.

Role of Thin Film Photovoltaics – If thin film photovoltaic modules find rapid acceptance in the marketplace, then the demand for crystalline silicon modules could be reduced, thus lessening the photovoltaic demand for polysilicon. On the other hand, if thin film modules are not widely accepted (less than 10% share), then the demand for photovoltaic polysilicon could increase above the forecasted scenarios.