

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, likely market scenarios are used to provide a five-year forecast of both supply and demand 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 many of the current and future polysilicon producers. A two page description of many of the existing and planned polysilicon facilities is provided. Each description provides information on ownership, investment level, location, technology, and hired contractors, where available. The chapter concludes with a table summarizing much of the data contained in the individual discussions.

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 describes polysilicon use in the photovoltaic industry. It relates the demand for solar wafers and polysilicon created to the production of photovoltaic cells. It provides an overall description of the photovoltaic wafer industry and the polysilicon activities to supply this industry. The chapter closes with a photovoltaic wafer buyer / seller matrix and a photovoltaic polysilicon buyer / seller matrix.

Chapter 6 - The chapter describes the silicon wafer and silicon raw material flow through each of the top photovoltaic cell producers. A flow chart is provided for each company illustrating their module and cell production by location and the flow of silicon to support that production.

Chapter 7 - The chapter then describes the silicon raw material flow for the suppliers of photovoltaic wafers. A flow chart is provided for each wafer company illustrating where their wafers are produced and the amounts of polysilicon needed to support their wafer production activities.

Chapter 8 - 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 2012 are presented for GDP, Electronic Systems, Integrated Circuits, and silicon materials needed by the semiconductor industry.

Chapter 9 - 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 10 - Polysilicon Supply And Demand Forecast – Market forecasts of semiconductor and photovoltaic industries' product demand are combined to estimate a most likely scenario of polysilicon demand volume. The supply is supplied by a company by company analysis of current and anticipated players.

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 author's individual experience of more than 20 years is 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 had 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. For years (1975-2003) the photovoltaic industry had no viable supply chain of the silicon raw material. 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 being currently planned are for far more supply than necessary.

- Existing polysilicon producers and new comers have plans to have an accumulative investment of \$40 billion by the year 2015.

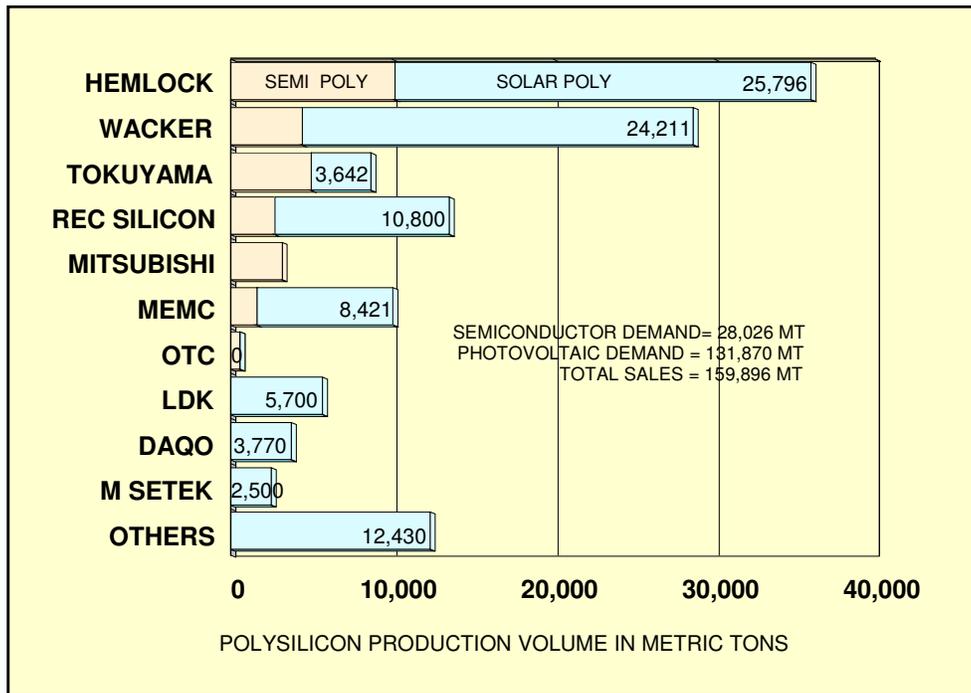


- These investments are to provide 523,190 metric tons of new silicon raw material by the year 2015.
- While Sage Concepts does not believe all of the silicon raw material projects will be completed on time, it does expect there to be at least 400,000 metric tons to be available by the year 2015.

1.3.1 CURRENT SILICON RAW MATERIAL SUPPLY

The current supply of polysilicon is illustrated in Figure 1-1. The semiconductor polysilicon supply in 2010 was 28,026 metric tons and the photovoltaic supply was 131,870 metric tons. Total photovoltaic polysilicon supply was 159,896 metric tons.

FIGURE 1-1
2010 POLYSILICON SUPPLY
(in Metric Tons)



The largest polysilicon supplier is Hemlock Semiconductor. In 2010 Hemlock supplied 10,204 metric tons to the semiconductor industry and 25,796 metric tons to the photovoltaic industry for a total of 36,000 metric tons. The position of 2nd largest polysilicon supplier was held by Wacker Chemie. In 2010 Wacker supplied 4489 metric tons to the semiconductor industry. Most of this material was shipped to its sister company, Siltronic AG. In addition it supplied 24,211 metric tons of polysilicon to the photovoltaic industry for a total of 28,700 metric tons. The 3rd largest polysilicon supplier was the Chinese company, GCL Poly, which supplied 17,000 metric tons in 2010. In 4th position was the South Korean company, OCI. In 2010 OCI supplied 17,000 metric tons, mostly to the solar industry. In 5th position was traditional supplier REC Silicon. Its Butte, Montana, plant supplied 2800 metric tons to the semiconductor industry. In addition its Moses Lake, Washington, plant supplied 10,800 metric tons to the photovoltaic industry. The sales of these two plants together supplied 13,600 metric tons.

In 6th position is MEMC which produced 10,096 metric tons in 2010. Some 1675 metric tons were used internally to produce semiconductor wafers and 8421 metric tons were used to produce photovoltaic wafers. Following MEMC is Tokuyama. Tokuyama supplied 5058 metric tons to the semiconductor industry and 3642 metric tons to the photovoltaic industry for a total of 8700 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 Osaka Titanium Technology (ex-Sumitomo Titanium) is dedicated to the production of polysilicon to the semiconductor industry. In 2010 the Japanese plants of Mitsubishi and OTC were shut down for a half a year for safety upgrades.

In 2010 Chinese producer LDK produced 5700 metric tons and another Chinese producer, Daqo, produced 3770 metric tons. In Japan new producer M Setek produced 2500 metric tons for use in the production of solar wafers. Additionally several other small polysilicon companies, UMG providers, and scrap resellers combined to supply another 12,430 metric tons of polysilicon in 2010.

1.3.2 KEY FINDINGS

- The polysilicon industry oversupply condition has been moderated. On the supply side many plans have been mollified by problems with production cost and quality. On the demand side most companies have been factoring a 4 to 5 month lead-time into their purchase decisions.
- Current polysilicon expansion plans would result in a capacity of 523,190 metric tons by the year 2015, based on Sage Concepts' assessment the industry's ability to produce.
- The semiconductor and photovoltaic industries both grew rapidly in 2010. Their combined demand nearly reached the polysilicon industry's ability to produce. The tight supply and demand situation caused polysilicon prices to increase in 2010.
- Semiconductor polysilicon demand increased from 20,016 metric tons to 28,026 metric tons, an increase of 40%.
- In 2010 photovoltaic polysilicon demand increased from 72,212 metric tons to 131,870 metric tons, an increase of 82.6%.
- As a result of oversupply polysilicon prices are anticipated to drop over the next five years.
- In terms of silicon wafer area, the semiconductor industry consumed 9342 million square inches and the photovoltaic industry consumed 149,284 million square inches, rendering the semiconductor wafer area to only 5.9% of the total.

1.3.3 POLYSILICON SUPPLY AND DEMAND SUMMARY

With 523,190 metric tons of supply forecast by 2015, there should be ample silicon raw material available for each of the demand scenarios presented later in Tables 9-(2-4). Under the anticipated scenario (PV CAGR = 12%), the demand for silicon raw material should reach 258,381 metric tons in 2015, thus resulting in a potential oversupply of over 264,809 metric tons.

Figure 1-2 is a plot of the Sage Concepts' demand forecast superimposed atop its supply forecast. This figure indicates that this demand level could be more than satisfied by the first two groups out to the year 2015. The figure also shows that Tier 1 supplier could provide all of the polysilicon necessary to supply the needs of both the semiconductor and photovoltaic industries out to the year 2015. If Tier 2 and Tier 3 suppliers continue with their aggressive expansion plans, the polysilicon market could see nearly a 100% oversupply by 2015.

FIGURE 1-2
2010 POLYSILICON SUPPLY AND DEMAND FORECAST

