

Proposed Global & India Market Research Analysis & Demand

Assessment of Polysilicon & Monosilane

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**Product Overview:**

**Polysilicon**

Polysilicon, a high-purity form of silicon, is a key raw material in the solar photovoltaic supply chain. Polysilicon ingots are melted at high temperatures to produce solar modules, which are then sliced into wafers and processed into solar cells and modules. It is a major material used in making semiconductor chips and solar cells. Polysilicon is produced from three processes namely Siemens process, fluidized bed reactor, Upgraded Metallurgical-Grade Silicon Process.

**4. Polysilicon Demand Supply Scenario Assessment, 2021**

**4.1.** **Global Overview of Major Producing Countries by Production Output**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Region** | **Country** | **2017** | **2018** | **2019** | **2020** | **2021** | **2022E** | **2023F** | **2024F** | **2025F** | **2030F** |
| Asia Pacific | India | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 25 |
| Asia Pacific | China | 235 | 291 | 337 | 452 | 489 | 556 | 1006 | 1106 | 1521 | 2011 |
| Asia Pacific | Japan | 9 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Asia Pacific | Malaysia | 10 | 10 | 27 | 27 | 30 | 35 | 35 | 35 | 35 | 35 |
| Asia Pacific | South Korea | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| **Asia Pacific** | **Asia Pacific** | **257** | **310** | **373** | **488** | **528** | **600** | **1050** | **1150** | **1575** | **2080** |
| Europe | Germany | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| **Europe** | **Europe** | **60** | **60** | **60** | **60** | **60** | **60** | **60** | **60** | **60** | **60** |
| **Americas** | USA | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 |
| **Americas** | **Americas** | **76** | **76** | **76** | **76** | **76** | **76** | **76** | **76** | **76** | **76** |
| **Global** | **Total** | **393** | **446** | **509** | **624** | **664** | **736** | **1186** | **1286** | **1711** | **2216** |

Polysilicon is the basic semiconductor material utilized in the assembling of the most used kind of solar based photovoltaic (PV) cells as well as the ubiquitous integrated circuit (IC) chips. With expanded significance of environmentally friendly power, the manufacturing of polysilicon worldwide has expanded from hundreds to thousands of tons. Among the major producing countries, China holds around 75% of the total production capacities in the world and is likely to capture 90% market in the forecast period due to massive capacity expansions of Chinese players. These reports should be a reminder for western countries. If these countries did not expand their capacities of polysilicon in the coming years, then would end up depending fully on imports by China for solar related energy. The countries should implement an effective policy or strategy for a non – Chinese solar supply chain, particularly for polysilicon.

**4.2. Production Capacity and Actual Production Statistics by Leading Companies, 2021**

|  |  |  |
| --- | --- | --- |
| **Company** | **Capacity (KT)** | **Production (KT)** |
| Tongwei Company Limited | 100 | 96.52 |
| GCL Poly Energy Holdings Limited | 90 | 87.58 |
| Wacker Chemie AG | 80 | 74.75 |
| Xinte Energy Co | 80 | 73.09 |
| Daqo New Energy Corp | 70 | 67.56 |
| Xinjiang East Hope New Energy Company | 40 | 38.27 |
| REC Silicon | 40 | 36.32 |
| Hemlock Semiconductor Corporation | 36 | 34.13 |
| OCI Company Limited | 30 | 26.42 |
| Asia Silicon (Quinghai) Limited | 20 | 18.33 |

**4.3. Demand Supply Gap Analysis (in terms of Actual Production vs. Consumption), 2017-2030**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Description** | **2017** | **2018** | **2019** | **2020** | **2021** | **2022E** | **2023F** | **2024F** | **2025F** | **2029F** | **2030F** |
| Capacity | 393 | 446 | 509 | 624 | 664 | 736 | 1186 | 1286 | 1711 | 2216 | 2216 |
| Production | 374 | 425 | 493 | 543 | 627 | 665 | 1075 | 1157 | 1548 | 2052 | 2055 |
| Import | 26 | 27 | 23 | 14 | 20 |  | | | | | |
| Export | 26 | 27 | 23 | 14 | 20 |
| Domestic Consumption By Volume (Kilo Tonnes) | 374 | 425 | 493 | 543 | 627 | 692 | 785 | 917 | 1089 | 2369 | 2934 |
| Demand-Supply Gap | 0 | | | | | **-27** | 289 | 241 | 459 | **-317** | **-879** |

The above table shows the total production capacity available for polysilicon production with the historical and forecasted production figures. According to the data, there will be significant demand supply gap in 2022 as there will not be enough capacity expansions in the year but in 2023, surplus in supply of polysilicon is expected as massive capacity expansions are planned in the coming year. Moreover, massive undersupply is anticipated in the years 2029 and 2030 due to rising demand of PV cells would be seen for achieving the net zero emission target by most of the western countries.

**4.4. Overview of major end use verticals and consumers with apparent consumption volume**

**4.5. Outline of Imports by Top 10 countries (including India) and Exporting Countries, 2017-2021**

**Top 10 Polysilicon Importing Countries,** **By Volume (Kilo Tonnes), By Value (USD Million), 2017-2021**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Importing Countries** | **2017** | | **2018** | | **2019** | | **2020** | | **2021** | |
| **Volume** | **Value** | **Volume** | **Value** | **Volume** | **Value** | **Volume** | **Value** | **Volume** | **Value** |
| Japan | 2.86 | 115.65 | 2.71 | 109.89 | 1.84 | 70.16 | 1.50 | 59.86 | 1.49 | 66.35 |
| Germany | 0.40 | 10.82 | 0.13 | 3.23 | 0.62 | 11.22 | 0.48 | 16.49 | 0.61 | 16.20 |
| China | 0.55 | 8.83 | 1.25 | 8.89 | 0.76 | 7.20 | 0.13 | 4.27 | 0.21 | 5.19 |
| USA | 0.18 | 8.73 | 0.17 | 10.31 | 0.16 | 11.41 | 0.09 | 8.27 | 0.19 | 12.85 |
| South Korea | 0.31 | 0.39 | 0.13 | 0.28 | 0.26 | 0.46 | 0.25 | 0.39 | 0.19 | 0.68 |
| Malaysia | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 | 0.85 | 0.17 | 1.69 |
| Indonesia | 0.10 | 2.76 | 0.07 | 2.58 | 0.08 | 1.62 | 0.05 | 0.68 | 0.14 | 1.78 |
| Brazil | 0.04 | 0.30 | 0.04 | 0.28 | 0.04 | 0.14 | 0.03 | 0.08 | 0.04 | 0.13 |
| Vietnam | 0.01 | 1.18 | 0.02 | 1.27 | 0.00 | 0.63 | 0.00 | 0.00 | 0.03 | 0.11 |
| Italy | 0.01 | 1.26 | 0.05 | 1.35 | 0.01 | 0.36 | 0.00 | 0.32 | 0.02 | 0.10 |
| Others | 21.53 | 333.74 | 22.02 | 344.56 | 18.97 | 216.94 | 11.50 | 128.42 | 17.08 | 358.48 |
| **Total** | **25.98** | **483.67** | **26.59** | **482.65** | **22.75** | **320.14** | **14.13** | **219.63** | **20.16** | **463.57** |

**Top Polysilicon Exporting Countries, By Volume (Kilo Tonnes), By Value (USD Million), 2017-2021**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Exporting Countries** | **2017** | | **2018** | | **2019** | | **2020** | | **2021** | |
| **Volume** | **Value** | **Volume** | **Value** | **Volume** | **Value** | **Volume** | **Value** | **Volume** | **Value** |
| China | 15.53 | 294.44 | 17.35 | 323.69 | 15.06 | 226.14 | 10.24 | 170.05 | 14.84 | 358.85 |
| USA | 5.02 | 95.22 | 4.53 | 84.54 | 3.40 | 51.00 | 1.72 | 28.59 | 2.31 | 55.77 |
| Germany | 3.97 | 75.18 | 3.58 | 66.74 | 2.68 | 40.26 | 1.36 | 22.57 | 1.82 | 44.03 |
| Malaysia | 0.66 | 12.53 | 0.60 | 11.12 | 1.21 | 18.12 | 0.61 | 10.16 | 0.91 | 22.02 |
| Japan | 0.59 | 11.28 | 0.36 | 6.67 | 0.27 | 3.28 | 0.14 | 2.26 | 0.18 | 4.40 |
| South Korea | 0.20 | 3.76 | 0.18 | 3.34 | 0.13 | 2.76 | 0.07 | 1.13 | 0.09 | 2.20 |
| **Total** | **25.98** | **492.40** | **26.59** | **496.10** | **22.75** | **341.56** | **14.13** | **234.76** | **20.16** | **487.27** |

**4.6. India Market Assessment by Domestic Produce vs. Imports in existing and upcoming scenario**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Company** | **2017** | **2018** | **2019** | **2020** | **2021** | **2022E** | **2025F** | **2026F** | **2027F** | **2028F** | **2029F** | **2030F** |
| **Capacity (KT)** | 0 | 0 | 0 | 0 | 0 | 0 | **10** | **10** | **20** | **20** | **25** | **25** |
| **Production (KT)** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.50 | 4.40 | 11.40 | 11.60 | 14.75 | 15.00 |
| **Import (KT)** | 0.03 | 0.02 | 0.02 | 0.07 | 0.00 |  | | | | | | |
| **Export (KT)** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Domestic Consumption (KT)** | 0.03 | 0.02 | 0.02 | 0.07 | 0.00 | 0.01 | 0.18 | 1.68 | 2.31 | 4.41 | 6.21 | 7.57 |
| **ASP (USD/Kg)** | 17.75 | 14.76 | 9.87 | 9.69 | 26.00 | 20.53 | 13.15 | 12.72 | 13.00 | 13.18 | 13.53 | 13.81 |
| **Demand-Supply Gap (KT)** | 0 | | | | | **0** | **2** | **3** | **9** | **7** | **9** | **7** |

India needs a sustainable, vertically integrated domestic solar manufacturing ecosystem. Dozens of companies are vying to make a mark in the Indian solar sector. Favourable scenarios have generated huge interest for companies to invest in India although currently there has been no production capacity of polysilicon and related solar energy products, but the country has got the huge potential in the solar industry. Some of the key drivers which stimulates the investment in India are-

* Favourable government policy environment
* Augmentation of required demand
* Availability of raw materials
* Easier financing options
* Predicted technological changes

**5. Global Polysilicon Market Outlook**

**5.1. Market Size & Forecast, 2017-2030**

**5.1.1. By Value**

**Global Polysilicon Market Size, By Value (USD Million), 2017-2030F**

**2022E – 2030F**

**CAGR**

**14.00%, By Value**

**2017 – 2021**

**CAGR**

**24.61%, By Value**

**5.1.2. By Volume**

**Global Polysilicon Market Size, By Volume (Kilo Tonnes), 2017-2030F**

**2022E – 2030F**

**CAGR**

**19.79%, By Volume**

**2017 – 2021**

**CAGR**

**13.81%, By Volume**

**5.2. Market Share & Forecast 2017-2030**

**5.2.1. By Grade (High Purity Silicon Grade, Secondary/ Off- Grade, Recycled)**

**Global Polysilicon Market Share, By Grade, By Volume (Kilo Tonnes), 2017-2030F**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **By Grade (KT)** | **2017** | **2018** | **2019** | **2020** | **2021** | **2022E** | **2023F** | **2024F** | **2025F** | **2030F** |
| High Purity Silicon Grade | 33 | 37 | 43 | 48 | 56 | 62 | 70 | 82 | 98 | 264 |
| Secondary/ Off- Grade | 324 | 369 | 430 | 475 | 551 | 609 | 691 | 807 | 959 | 2586 |
| Recycled Grade | 18 | 19 | 20 | 20 | 20 | 22 | 24 | 28 | 33 | 84 |
| **Total** | **374** | **425** | **493** | **543** | **627** | **692** | **785** | **917** | **1089** | **2934** |

**5.2.2. By Application (PV Cell Feedstock, VLSI Gate Electrodes & Interconnecting Components, Resistors/Conductors/Ohmic Contacts)**

**Global Polysilicon Market Share, By Application, By Volume (Kilo Tonnes), 2017-2030F**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **By Application (KT)** | **2017** | **2018** | **2019** | **2020** | **2021** | **2022E** | **2023F** | **2024F** | **2025F** | **2030F** |
| PV Cell Feedstock | 346 | 394 | 457 | 505 | 582 | 643 | 730 | 852 | 1013 | 2732 |
| VLSI Gate Electrodes & Interconnecting Components | 19 | 22 | 25 | 29 | 33 | 38 | 43 | 51 | 60 | 162 |
| Resistors/Conductors/Ohmic Contacts | 9 | 10 | 10 | 10 | 11 | 11 | 12 | 14 | 16 | 40 |
| **Total** | **374** | **425** | **493** | **543** | **627** | **692** | **785** | **917** | **1089** | **2934** |

**5.2.3. By Region (East Asia, Americas, Europe, South Asia & Pacific, Middle East & Africa)**

**Global Polysilicon Market Share, By Region, By Volume (Kilo Tonnes), 2017-2030F**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **By Region (KT)** | **2017** | **2018** | **2019** | **2020** | **2021** | **2022E** | **2023F** | **2024F** | **2025F** | **2030F** |
| East Asia | 306 | 349 | 405 | 446 | 518 | 572 | 650 | 758 | 901 | 2429 |
| Americas | 18 | 21 | 23 | 27 | 31 | 34 | 38 | 44 | 52 | 134 |
| Europe | 25 | 28 | 33 | 37 | 43 | 47 | 53 | 62 | 73 | 192 |
| South Asia & Pacific | 10 | 10 | 12 | 11 | 13 | 15 | 17 | 20 | 25 | 69 |
| Middle East & Africa | 15 | 18 | 20 | 22 | 21 | 24 | 27 | 32 | 38 | 110 |
| **Total** | **374** | **425** | **493** | **543** | **627** | **692** | **785** | **917** | **1089** | **2934** |

**6. Global Off-Spec Grade Polysilicon Market Outlook by Region and Utilization by Application**

Secondary Off- Grade has purity level of 6N to 8N and is used usually in manufacturing of solar photovoltaics.

**6.1. By Value**

**Global Off-Spec Grade Polysilicon Market Size, By Value (USD Million), 2017-2030F**

**2022E – 2030F**

**CAGR**

**14.12%, By Value**

**2017 – 2021**

**CAGR**

**24.74%, By Value**

**6.2. By Volume**

**Global Off-Spec Grade Polysilicon Market Size, By Volume (Kilo Tonnes), 2017-2030F**

**2022E – 2030F**

**CAGR**

**19.82%, By Volume**

**2017 – 2021**

**CAGR**

**14.23%, By Volume**

**7. India Polysilicon Market Outlook**

**7.1. Market Size & Forecast, 2017-2030**

**7.1.1. By Value**

**India Polysilicon Market Size, By Value (USD Million), 2017-2030F**

**2022E – 2030F**

**CAGR**

**117.96%, By Value**

**2017 – 2021**

**CAGR**

**-60.21%, By Value**

**7.1.2. By Volume**

**India Polysilicon Market Size, By Volume (Kilo Tonnes), 2017-2030F**

**2017 – 2021**

**CAGR**

**-63.83%, By Volume**

**2022E – 2030F**

**CAGR**

**129.03%, By Volume**

**7.2. Market Share & Forecast, 2017-2030**

**7.2.1. By Grade (High Purity Silicon Grade, Secondary Grade, Recycled)**

**India Polysilicon Market Share, By Grade, By Volume (Kilo Tonnes), 2017-2030F**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **By Grade (KT)** | **2017** | **2018** | **2019** | **2020** | **2021** | **2022E** | **2023F** | **2024F** | **2025F** | **2030F** |
| High Purity Silicon Grade | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.32 |
| Secondary/ Off- Grade | 0.03 | 0.02 | 0.02 | 0.07 | 0.00 | 0.01 | 0.03 | 0.04 | 0.17 | 7.25 |
| Recycled Grade | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | **0.03** | **0.02** | **0.02** | **0.07** | **0.00** | **0.01** | **0.03** | **0.04** | **0.18** | **7.57** |

**7.2.2. By Application (PV Cell Feedstock, VLSI Gate Electrodes & Interconnecting Components, Resistors/Conductors/Ohmic Contacts)**

**India Polysilicon Market Share, By Application, By Volume (Kilo Tonnes), 2017-2030F**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **By Application (KT)** | **2017** | **2018** | **2019** | **2020** | **2021** | **2022E** | **2023F** | **2024F** | **2025F** | **2030F** |
| PV Cell Feedstock | 0.03 | 0.02 | 0.02 | 0.07 | 0.00 | 0.01 | 0.03 | 0.04 | 0.18 | 7.55 |
| VLSI Gate Electrodes & Interconnecting Components | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| Resistors/Conductors/Ohmic Contacts | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | **0.03** | **0.02** | **0.02** | **0.07** | **0.00** | **0.01** | **0.03** | **0.04** | **0.18** | **7.57** |

**7.2.3. By Region (North India, West India, South India, East India) Overview of Key States by Each Region**

**India Polysilicon Market Share, By Region, By Volume (Kilo Tonnes), 2017-2030F**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **By Region (KT)** | **2017** | **2018** | **2019** | **2020** | **2021** | **2022E** | **2023F** | **2024F** | **2025F** | **2030F** |
| West | 0.03 | 0.02 | 0.02 | 0.07 | 0.00 | 0.01 | 0.03 | 0.04 | 0.18 | 7.35 |
| South | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 |
| North | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| East | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total** | **0.03** | **0.02** | **0.02** | **0.07** | **0.00** | **0.01** | **0.03** | **0.04** | **0.18** | **7.57** |

**7.3. Demand Supply Scenario**

**7.3.1. Overview of Imports by Country of Origin**

**Imports of Polysilicon Country wise (Value- USD Million, Volume- Metric Tonnes)**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Importing Countries** | **2017** | | **2018** | | **2019** | | **2020** | | **2021** | |
| **Value** | **Volume** | **Value** | **Volume** | **Value** | **Volume** | **Value** | **Volume** | **Value** | **Volume** |
| China | 0.01 | 0.02 | 0.00 | 0.00 | 0.02 | 0.01 | 0.08 | 0.05 | 0.00 | 0.00 |
| Japan | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 |
| Germany | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 |
| USA | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| South Korea | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Others | 0.01 | 0.00 | 0.08 | 0.00 | 0.02 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 |
| **Total** | **0.02** | **0.03** | **0.09** | **0.02** | **0.04** | **0.02** | **0.12** | **0.07** | **0.01** | **0.00** |

China, Japan, Germany, USA, South Korea are the major exporters. In 2020, China export 51MT of polysilicon in India.

**7.3.2. Overview of Domestic Producer**

In India, the polysilicon market is import-driven, there is not any manufacturing plant for polysilicon in India. In the forthcoming years, the government is planning to establish a manufacturing plant in the country by providing support to the companies through various schemes such as “Make in India” Initiatives, Solar programs, and PLI Scheme.

Four companies, Reliance New Energy, Adani Infrastructure, Jindal India Solar, and Shirdi Sai Electricals proposed to the government for 4GW solar factory that is fully integrated from polysilicon production through the wafer, solar cell, and module manufacturing. Shirdi Sai Electricals received the Letter of Award from the Indian Renewable Energy Development Agency for setting up its integrated 4 GW polysilicon-to-module factory under the PLI scheme. The PLI beneficiaries are Shirdi Sai Electricals, Reliance New Energy, and Adani Infrastructure.

Furthermore, Lanco Solar Private Ltd initiated manufacturing of polysilicon in 2011 with a modest production capacity of 1800MT, but due to several untoward circumstances, the company failed to establish itself. With the help of government initiatives, now the company is planning to manufacture 1500 TPA of 99.9999999% pure polysilicon from manufacturing-grade silica using hydrochlorination technology in India. It is the first composite polysilicon plant in India to use manufacturing-grade silica to produce solar-grade polysilicon.

**7.3.2.** **Overview of Key Customers**

The key customers of polysilicon in India are solar photovoltaic industry, semiconductor industry etc.

Key customers of polysilicon in solar photovoltaic industry:

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **Location** | **Types of Production** | **Production Capacity** |
| Tata Power Solar Systems Limited, | Bengaluru | Solar Modules and Cells | 1100 MW |
| Samsung India | Greater Noida, Uttar Pradesh | Mobile Phone | 60 million unit per year 2021. |
| PLG Power Limited | Nasik, Maharashtra | Multi – Crystalline and Mono-Crystalline Solar Photovoltaic Modules | 40 MW |
| Indosolar Ltd. | Greater Noida, Uttar Pradesh | Photovoltaic Cell | 500MW |
| XL Energy Ltd | Hyderabad, Andhra Pradesh | Solar Module | ~75MW |
| Surana Solar Limited | Gujarat and Telangana | Solar Photovoltaic Modules | 5MW each |
| Bharat Heavy Electricals Ltd | Bengaluru | Solar Module, Semiconductor | 465 MW (2021),65000PV modules per annum (2020) |
| Waa Solar Ltd | Gujarat | Photovoltaic | 10.25 MW |
| Foxconn India | Tamil Nadu | Smartphone | ~48 million per year |
| Lava International | Noida, Uttar Pradesh | Smartphone & Feature Phone | 4 crore feature phones and 2.6 crore smartphones per annum (2021) |
| Reliance JIO Mobiles | Chennai | Feature Phone | 165 million (2020) |
|  |  |  |  |

Source: TechSci Research

**8. Polysilicon Production Scenario Assessment**

**8.1.** **Planned Capacities by Key Countries vs. Actual Capacity Utilization Rate**

**Key Country Planned Capacity Vs Capacity Utilization Rate in 2021:**

|  |  |  |
| --- | --- | --- |
| **Country** | **Planned Capacity** | **Capacity Utilization Rate (%)** |
| China | 489 | 95% |
| Japan | 6.2 | 92% |
| Malaysia | 30 | 88% |
| South Korea | 3 | 92% |
| Germany | 60 | 94% |
| United States | 76 | 94% |

Source: TechSci Research

China is a leader in the manufacture of polysilicon that used as raw material in solar panels. There are numerous companies involved in the manufacturing of polysilicon such as Tongwei Company Limited, Daqo New Energy Corp, GCL Poly Energy Holdings Limited, Xinte Energy Co, Xinjiang East Hope New Energy Company, Asia Silicon (Quinghai) Limited are the major manufacturers. The country has the highest planned capacity i.e., 489 with a capacity utilization rate is 95% followed by Japan, Malaysia, South Korea, Germany, and United States.

**8.2. Product Quality/ Grade and Development Trends**

Solar Photovoltaics is a fast-evolving industry, where polysilicon is used as raw materials. Polysilicon is the feedstock for the solar and semiconductor industries. The solar photovoltaics market is optimistic about demand in the foreseeable future. Henceforth, major manufacturers are increasing capital spending and expanding polysilicon production operations to position themselves to capitalize on the growth. Polysilicon manufacturing companies across the globe manufacture polysilicon with the purity levels of 6N to 8N (Secondary/ Off- Grade) for solar photovoltaics, 9N to 11N (High Purity Silicon Grade) for semiconductors. Moreover, these companies manufacture polysilicon with a purity level of 9N as this grade is also used in some premium solar cells.

Nowadays, there is rising trend of recycled polysilicon. The aluminium, glass, and copper from discarded modules are currently recycled all around the world. However, there is no method for recycling silicon solar cells. Researchers from the Fraunhofer Center for Silicon Photovoltaics CSP and the Fraunhofer Institute for Solar Energy Systems ISE, in collaboration with Reiling GmbH & Co. KG, Germany's largest PV module recycling company, developed a solution in which the silicon in discarded modules is recycled on an industrial scale and reused to produce new PERC solar cells. Now, recycled silicon used in 19.7% efficient PERC Solar cells.

**There are three main technologies to produce polysilicon:**

|  |  |  |
| --- | --- | --- |
| **Siemens Process** | **Fluidised Bed Reactor Process** | **Upgraded Metallurgical-Grade Silicon Process** |
| **Features and Advantages:**   * Siemens process is the most widely used technology to produce high-quality pure polysilicon. * This process manufactures polysilicon with a purity level of 9N-11N and uses an energy intensity of 60-80 (KWh/Kg). * It requires cycle time of 60-150hrs. * This method recycles all the various components in the tail gas, which can reduce the consumption of raw materials. * This process is a closed loop system, various materials used in polysilicon production are fully utilized and discharged. Hence, there is very little waste.   **Disadvantage of siemens process**   * It is batch process so there is loss of downtime and require setup effort. * This process requires important security measures due to the handling of hydrogen and hydrochloric acid. | **Features and Advantages:**   * A fluidized bed reactor is a less mature technology and is used by a few polysilicon producers. * This process manufactures polysilicon with a purity level of 6N-9N and uses an energy intensity of ~55 (KWh/Kg). * It does not waste energy by placing heated gas and silicon in contact with cold surfaces. * It produces more silicon per cubic meter of reactor space because the silicon crystals have a larger total surface area. * It is a continuous process. so, there is less wasted downtime, and do not require setup effort. * And finally, unlike the Siemens process which requires the breaking of polysilicon rods, FBR granular is harvested in a ready to use form. * FBR granular polysilicon can be packaged in bulk containers, increases logistics efficiency.   **Disadvantage:**   * It requires high cycle time of 60-120 days. | **Features and Advantages:**   * UMG uses physical methods to extract impurities directly from silicon metal instead of chemical processes, which reduces energy usage. * Silicon produced using UMG process is not widely used. * This process manufactures polysilicon with purity level of 6N.   **Disadvantages:**   * It has limited capacity. * It requires high cost * This process does not produce polysilicon of high purity level. |

**Technologies with Purity Level:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | 6N | 7N | 8N | 9N | 10N | 11N |
| **Siemens Process** |  |  |  |  |  |  |
| **Fluidised Bed Reactor Process** |  |  |  |  |  |  |
| **Upgraded Metallurgical-Grade Silicon Process** |  |  |  |  |  |  |

Source: TechSci Research

**Upgraded Metallurgical-Grade Silicon Process**

**Siemens Process**

**Fluidised Bed Reactor Process**

**Technologies Usage:**

Source: TechSci Research

**8.3. Overview of Production Process and Existing Plant Configurations\*\***

There are three main production method of polysilicon:

* **Siemens process:**

The Siemens Process is the dominant process to produce polysilicon for electronics and photovoltaics from MG-Si. It is similar to distillation, so that silicon reacts with HCl gas in a reactor at about 300°C: Si(s)+3HCl(g)=SiHCl3(g)+H2(g). Then the trichlorosilane gas will thermally decompose on heated silicon rods (>1300°) in a hydrogen atmosphere: SiHCl3(g)+H2(g)=Si(s)+3HCl(g).

To remove the 0.5% to 1.5% impurities contained in metallurgical-grade (MG) silicon, the siemens process creates trichlorosilane, a highly volatile liquid, as an intermediate product.

For that purpose, MG silicon is ground up into small particles which react with hydrogen chloride (HCl). The resulting TCS has a low boiling point of 31.8 degrees centigrade (°C) so that it can be purified in tall distillation columns relatively easily.

Silicon is then deposited from the TCS on highly pure, slim silicon filaments that are electrically heated to up to 1,150 °C in a steel bell-jar reactor until they have grown to polysilicon rods with a diameter of 15 to 20 cm. This energy-intensive step is called chemical vapor deposition (CVD). The long rods are broken into small chunks. The by-product silicon tetrachloride is recycled to TCS mostly through hydrochlorination: STC is fed along with hydrogen (H2) and MG silicon particles into the reactor for TCS production. Depending on how thoroughly TCS is distilled and whether impurities on the surface of the polysilicon chunks are etched off, different levels of polysilicon purity are achieved: solar grade for multicrystalline cells 7N to 8N, a solar grade for monocrystalline cells 9N to 10N, an electronic grade for semiconductors 10N to 11N.

* **Fluidized Bed Reactor:**

With the Fluidized Bed Reactor process, REC Silicon has taken a major step forward in silicon purification using less energy. Instead of using seed rods, FBR uses seed granules of purified silicon. The seed granules are fed into a chamber that has heated silane gas entering from below and exiting above. The flow of gas “fluidizes” the silicon granules, causing them to flow like a liquid, as the silane gas breaks down and deposits silicon layers on them. The granules grow larger and heavier and exit when they are sufficiently large. As they do so, new seed granules and gas are introduced into the chamber and the process continues.

* **Upgraded Metallurgical-Grade Silicon:**

Unlike in the standard production process for polysilicon, manufacturers of upgraded metallurgical-grade (UMG) silicon do not pursue a chemical route to purify the raw material of metallurgical-grade silicon Instead, they use physical methods, such as vacuum melting of the silicon metal, blowing of reactive gases through the melt, treating it with slags, leaching of solidified and crushed silicon with acids or directional solidification of molten silicon. All these methods serve to extract impurities directly from the silicon. This method consumes much less energy than the standard Siemens process. Initially, this method only reached a purity of 5N, and then it improved to 6N.

**9. Polysilicon Usage Assessment**

**9.1. Usage Analysis of Individual Grades by Respective End Use**

* **High Purity Silicon Grade:** High purity silicon grade has purity level of 9N to 11N. The high purity silicon grade is used in manufacturing of solar photovoltaics and semiconductors.
* **Secondary Off- Grade:** Secondary Off- Grade has purity level of 6N to 8N. The Secondary Off- Grade poly silicon grade is usually used in the manufacturing of solar photovoltaics.
* **Recycled:** Purity level of recycled polysilicon is not defined. The recycled polysilicon is planned to reuse to produce new PERC solar cells.

**9.2. Usage Analysis of Polysilicon by Products**

**9.2.1. Hydrogen**

Hydrogen is found as the by-product of polysilicon production. According to the Norwegian polysilicon manufacturer Elkem Bremanger, surplus hydrogen would be suitable for passenger vehicles. Once dried and compressed it could power 1,000 cars per year. The company is working with independent research institute SINTEF to check the quality of hydrogen. In Addition to it, Elkem Bremanger has received funding to develop hydrogen capture technology and to properly use of hydrogen gas to avoid wastage.

**9.2.2. Silicon Tetrachloride**

Silicon tetrachloride is a by-product in the production of polysilicon. For each ton of polysilicon produced, at least four tons of silicon tetrachloride liquid are generated. When polysilicon gas plants had production capacities below 1,000 metric tons per year, the by-product gas from both the gas plant and the Siemens deposition reactor was often burned, especially in non-integrated facilities.

Now, by-product silicon tetrachloride is recycled to the hydrochlorination reactor in an integrated plant or distilled and sold as a separate by-product in a non-integrated polysilicon plant. The polysilicon gas plants with production capacities exceeding 10,000 metric tons per year now have the economic incentive to recover the by-product gases and recycle them efficiently to the gas plant in an integrated facility. In a non-integrated plant, current technology allows for 'closed loop' operation by converting STC back to feedstock TCS, which is recycled to the Siemens reactor for polysilicon deposition.

**10. Polysilicon Pricing Analysis**

**10.1. Historical Pricing Analysis (USD/Kg), 2017 - 2021**

**10.2. Forecasted Pricing Forecast (USD/Kg), 2022E – 2030F**

Polysilicon prices have been steadily climbing since February 2021, reaching new highs in the last four months, with the average selling price reaching peaks without VAT in December. Despite the fact that polysilicon production in China surged in the first two months of 2022, polysilicon prices are now remarkably high. The surge in the prices have impacted the whole PV value chain of renewable energy. According to the various industry experts the prices are unlikely to fall until 2023. The extended hostilities between Eastern European nations have drastically impacted the trade dynamics and provoked fear of a steep surge in prices among domestic market players, forcing them to build up inventories. Moreover, the ongoing conflict between Russia and Ukraine led to the whole value chain and supply chain disruption. Prices of the materials witnessed a sharp rise due to this conflict. Furthermore, the steep rise in the prices of raw material has also accounted for the surge in price of polysilicon.

**11. Raw Material / Feedstock Price trends (USD/Kg), 2017 - 2021**

The market proficiency prompted the price decline in the 2018–2020 period. Demand has increased since 2020, and prices have risen as a result. The enormous excess of accumulated manufacturing facilities that would not be employed for several years was projected to restrain price growth to some extent. However, due to a decline in China supply, the price of metallurgical grade silicon increased in 2021. Prices increased by 300 percent from September to October 2021. The drop in production was driven by a Chinese energy crisis that affected nearly half of the country's businesses.

China's new air pollution reduction policy is the reason for the energy scarcity. The Chinese government's objectives to erase carbon footprints by 2060, as well as their commitment to environmentally safe and low-carbon development, are detailed. The coal industry provides 56 percent of China's energy, but the Chinese government has imposed tight environmental restrictions on coal extraction and established peak energy consumption limits across the country. The energy deficit has impacted at least 44% of China's businesses, leading many to shut down, including those producing metallurgical grade silicon.

Because a substantial portion of Chinese metallurgical grade silicon manufacturing facilities are in the Xinjiang Uygur Autonomous Region, the Chinese government's policy toward which has been severely criticised, the price has been heavily influenced by US sanctions. Elkem ASA, a Norwegian manufacturer of silicones, silicon, and other silicon-containing products, has likewise ceased operations. As a result, the price of metallurgical grade silicon has risen from 1.2–2.6 $/t to 10.4 $/t at its peak, and is now between 3 and 4 $/t.

**18.Global Solar Photovoltaics Industry Overview**

**Global**

Rising concerns about climate change, the health effects of air pollution, energy security, and energy access, along with volatile oil prices in recent decades, have led to the need to produce and use an alternative, low-carbon technology such as renewables. Solar Photovoltaics is one of the fastest-growing, most mature, and cost-competitive renewable energy technology.

Considering various resource availability, significant market potential, and cost competitiveness, solar photovoltaics is expected to continue dominance over renewable energy in several regions over the next decade. The major factor driving the global solar photovoltaics industry is the declining cost of solar photovoltaics and related equipment. In 2020, solar photovoltaic module prices reduced by more than 80%, as compared to that in 2010.

Globally, Asia would continue to dominate solar PV use, with over 50% of installed capacity, followed by North America (20%) and Europe (10%). Despite the COVID-19 pandemic, demand for solar in the European Union region increased to 18.2 GW in 2020 from 16.2 GW in 2019. The region is revising several policies and regulations to achieve its carbon-neutrality goal by 2050 which is expected to offer strong advantages to solar photovoltaics.

According to The International Renewable Energy Agency, globally the total installed capacity of solar Photovoltaics reached 480 GW in 2018 and is expected to reach 2840GW by 2030 and 8519GW by 2050. As of 2020, Asia-Pacific is the largest solar photovoltaics market across the globe and is expected to continue its dominance in the forthcoming year. China, Japan, and India are the key markets in the region.

**India**

India has made substantial progress in domestic solar module manufacturing capacity in recent years. Government of India is taking massive initiatives to support solar photovoltaics Industry in India.

**Schemes to Support Solar Industry in India by Government of India:**

|  |  |
| --- | --- |
| **Grid Connected** | **Solar Off grid** |
| Development of Solar Parks and Ultra Mega Solar Power Projects (Up to FY2022-FY23) | Off- Grid and Decentralized Solar PV Applications Programme -Phase III  (Till 31.03.2021) |
| Scheme for setting up of over 5000MW grid-connected SPV power projects under IV of JNNSM PHASE-II. (FY2015-FY16 to FY2018-FY19) | Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyaan (PM KUSUM)  (Till 31.12.2022) |
| Grid Connected Solar Rooftop Programme (Till 31.12.2022) | Atal Jyoti Yojana (AJAY): Phase III (Till 31.03.2020) |
| Scheme for setting up of distributed grid- connected solar PV Power projects in Andaman & Nicobar and Lakshadweep Islands with Capital Subsidy from MNRE (FY2016-FY17 to FY2019-FY20) | Scheme on Scale Up of Access to Clean Energy for Rural Productive Uses”  (Till June 2020) |
| Central public sector undertaking scheme phase II for setting up 12000MW grid- connected solar photovoltaic powder projects by the government producers with Viability Gap Funding support for self-use or use by government/ government entities , either directly or through distribution companies. | Seven Million Solar Study Lamp Scheme for School Going Children  (30.09.2019) |

Source: Ministry of New & Renewable Energy

According to the Ministry of New and Renewable Energy, India achieved the 5th global position in solar power deployment, and solar power capacity has increased by more than 11 times in the last five years from 2.6 GW in March 2014 to 30 GW in July 2019. India added a record 10 Gigawatt (GW) of solar energy to its cumulative installed capacity in 2021. As of 202, the country has now surpassed 50 GW of cumulative installed solar capacity.

Companies are continuously focussing on the expansion of solar photovoltaics through mergers and acquisitions, receiving funds, contracts, increasing manufacturing capacity, etc. For Instance, Solar Energy Corporation of India Ltd. implemented large-scale central auctions for solar parks and has awarded contracts for 47 parks with over 25 GW of combined capacity. Likewise, The NTPC is expected to commission India’s largest floating solar power plant in Ramagundam, Telangana by May June 2022. The expected total installed capacity is 447MW

**As on 31st March 2021 India’s solar plant installed capacity State-wise:**

Map

Description automatically generated with medium confidence

Source: Ministry of New & Renewable Energy

**Solar Power Park in India**

Map

Description automatically generated

Source: Ministry of New & Renewable Energy

**19. Macroeconomic Scenario Assessment**

**19.1. Polysilicon**

Consumption of polysilicon is directly dependent on consumption of solar photovoltaic industry and semiconductor industry. Globally, market size of semiconductor is around US$ 600 bn and is expected to rise in the forthcoming year whereas solar photovoltaic generation increased a record 156 TWh (23%) in 2020 to reach 821 TWh. Solar photovoltaic accounted for 3.1% of global electricity generation, and it remains the third-largest renewable electricity technology behind hydropower and onshore wind. Globally, China alone was responsible for 75% of the increase in annual solar PV installations from 2019 to 2020.

Rising demand from corporate through power purchase agreements, driven by declining costs and continued growth in residential and commercial markets, are driving the solar photovoltaic market.

The polysilicon market is depending on numerous factors including, logistic, import duties, consumption of polysilicon, Trade war, natural disaster etc. During 2020 & 2021, several companies entered the solar wafer market, increased the demand for polysilicon resulted in rise in price of polysilicon. In 2018, consumption of polysilicon in the solar photovoltaic industry in United states was impacted since United States government-imposed tariffs between 10% and 25% on solar module imports from China. Likewise, due to the outbreak of COVID-19 pandemic, production of polysilicon was affected as China is the largest producer of polysilicon almost 27% (510,000 ton ) of the China’s annual polysilicon capacity was affected.

**20.Polysilicon Market Dynamics**

**20.1 Drivers**

* **Growing Demand of Solar Photovoltaics panels:**
* Polysilicon is the major raw material used for solar photovoltaic panels. The rising need for alternate energy sources due to the depletion of fossil fuels across the globe is expected to increase the demand for solar photovoltaics, which in turn will drive the polysilicon market.
* Governments of developing and developed countries and industrial sectors are emphasizing the expansion of renewable energy sources, and solar energy has high potential. Thus, policymakers, regulatory bodies, and industrial sectors are investing enormously in the solar energy sector. This is generating remarkable demand for solar panels across the globe. In India, Solar power installed capacity has increased by more than 18 times from 2.63 GW in March 2014 to 49.3 GW at the end of 2021 and the government has an ambitious goal of 280GW of installed solar capacity by 2030, resulting in an increased market of polysilicon and monosilane market in India.
* **Government Initiatives:**
* To support the production of polysilicon, governments of various countries are promoting industrial policy with measures that included innovation funds, exemption of land fees, exemption on the electricity bill, low-rate loans, tax credits and grants, and public financing initiatives increasing investment in research & development of solar.
* In the USA, Solar Energy Manufacturing for America Act was introduced in the Senate, and the government would provide tax credits to American manufacturers at every stage of the solar panel manufacturing supply chain, from the production of polysilicon to solar cells to fully assembled solar modules.
* In India, government initiatives like the PLI scheme, Atmanirbhar Bharat, and Make in India Initiatives facilitate domestic manufacturing of polysilicon. The PLI scheme, which was approved by the central government in April, has a budget of US$611 million to promote 10 GW of integrated solar manufacturing capacity in India with an expected direct investment of around US$2.33 billion. Likewise, the Ministry of Electronics & Information Technology approved two specific schemes to reduce India's dependency on imports and build an ecosystem to produce semiconductors. The First Scheme, the design-linked incentive (DLI) scheme, aims to help budding Indian semiconductor design firms. The second scheme provides incentives for specialized fabs used to manufacture high frequency, high power, optoelectronic devices. It will also cover Assembly, Testing, Marking, and Packaging units of conventional silicon semiconductor chips. Assembly, Testing, Marking, and Packaging
* **Digital Evolution:**
* Digitalization is dominating many areas of everyday lives. The increased use of electronic items such as smartphones, laptops, digital music players, tablets, and desktop computers has increased the production of electronic gadgets, leading to the increased use of microchips. The microchips constitute polysilicon, resulting in driving the market of polysilicon market.
* **Increasing Mergers & Acquisitions, Joint Ventures, Investments:**
* To remain competitive in the market companies are continuously engaged in mergers & acquisitions, joint ventures, and investments to satisfy the demand for polysilicon in the market and to reduce the price.
* For instance, U.S.-based polysilicon manufacturer Hemlock Semiconductor has acquired the trichlorosilane (TCS) business of DuPont to better control supply and reduce costs by becoming vertically integrated in terms of polysilicon production.
* Likewise, JinkoSolar Holding Co., Ltd., a subsidiary company named Jinko Solar Co., Ltd. invested RMB450 million for equity in Sichuan Yongxiang Energy Technology Co., Ltd. a subsidiary of Tongwei Co., Ltd. for the construction of a high-purity polysilicon production line with an annual capacity of 100,000 tons.

**20.2 Challenges**

* **Unreliable Power Supply:**

Polysilicon production is an energy-consuming process (60-100 kWh/kg) and needs reliable power sources for continuous operations. An unreliable power supply is a crucial factor in the manufacturing of polysilicon. For Instance, there is not any manufacturing plant for polysilicon in India owing to high power tariffs and unreliable power supply. According to the Global Competitiveness Report 2019 of the World Economic Forum, India ranks 108th among 141 economies in the quality of electricity supply.

* **Volatile cost of polysilicon:**

The cost of polysilicon depends on numerous factors such as natural disasters, demand, supply, and labor force. With the advent of the pandemic, there is a rise in the price of polysilicon owing to a shutdown of manufacturing plants and fallen demand for solar photovoltaics panels across the globe. In 2021, polysilicon prices reached 10-year highs which were $36 per kg.

* **Supply Chain Barrier:**

Trade barriers, trade restrictions, unfair trade practices, the trade war between countries, and sudden outbreaks like the COVID-19 pandemic may adversely affect the polysilicon manufacturing companies to freely serve all markets. For Instance, the export of polysilicon manufacturing company named REC silicon was impacted due to the trade war between USA and China.

* **High Capital Requirements:**

The production of polysilicon requires large investments to build a plant, large corporate investment to learn and refine the production process, highly skilled Labor to operate the plant, and low electricity costs due to the large amount of energy needed to produce polysilicon.