Photovoltaic Report
Technology, Equipment and Materials

Sample report – PVTEM Abstract
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Introduction

• The most important objective for today’s photovoltaic (PV) market is to reduce the ratio of manufacturing cost to power output, and more specifically for solar modules, the manufacturing cost per kWh. With this in mind, technical solutions are required to reach grid parity and make PV a competitive energy source.

• Equipment and materials suppliers are partnering with cell manufacturers to cut cost down together. Investments in cell production capacity at an unprecedented level across multiple geographies will help manufacturers to benefit from learning and scale effects. However, innovation on equipment and material is a key parameter to sustain the growth of the PV industry.

• Increase technical performances to provide more efficient and time stable cells is the solution to leverage manufacturing cost. Along the value chain, numerous solutions are expected by PV manufacturers.

• PV industry has its own identity but can benefit from manufacturing solutions existing in various industry, semiconductor, display, printing, glass...

• Yole understood from its customers that maturity level of different PV technologies needed to be clarified. Some reached mass production through standard or proprietary manufacturing process. Others are still in development for bringing innovation at low cost. A strong variation is observed on equipment and materials needed in production between the different technologies.

• Yole’s objectives through this report, were to point out specific challenges and issues for each process, to bring key answers and to evaluate the potential market for equipment and material suppliers. Suppliers of lasers, screen printers, wet benches, furnaces, CVD and PVD systems... and all associated materials must all be aware of the photovoltaic market
Executive Summary
PV industry Status
Technology Comparison - Development Status

<table>
<thead>
<tr>
<th>Technology</th>
<th>2008</th>
<th>2010 status</th>
<th>2015 status</th>
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<tbody>
<tr>
<td>Si Wafer based (Mono and Polycrystalline)</td>
<td>Mass production</td>
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<tr>
<td>Amorphous (a-Si)</td>
<td></td>
<td>Mass production</td>
<td></td>
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<td>Tandem a-Si / Si Crystalline</td>
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<td>Mass production</td>
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<td>Thin film Si Crystalline</td>
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<td></td>
<td>Mass production</td>
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<tr>
<td>CIS / CIGS</td>
<td>Industrial research</td>
<td></td>
<td>Mass production</td>
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<tr>
<td>CdTe</td>
<td></td>
<td></td>
<td>Mass production</td>
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<tr>
<td>III V</td>
<td>Industrial research on concentrator; Mass production for cells</td>
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<td>Mass production</td>
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<tr>
<td>Dye Sensitized</td>
<td>Industrial research and pilot plant</td>
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<td>Mass production</td>
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<tr>
<td>Full Organic</td>
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<td>Mass production</td>
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<tr>
<td>Hybrid</td>
<td>Experimental research</td>
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</table>
Executive Summary
Production Forecast

C-Si production capacity

- 48% CAGR on 2006-2012 period
- Starting from less than 5GW in 2006 global production capacity multiplied by 11 in 6 years.
Executive Summary
Silicon-Based - a-Si and a-Si/µ-Si
Flow Chart
**Production forecast**

**Silicon situation**

**Polysilicon production capacity in 2007 – fab and volume per country**

- This graphic shows the production capacity of c-Si cells per country and the number of fabs associated.
- In 2007, only established poly-Si manufacturers had a fab.
- Silicon for PV was still recycled from the semiconductor demand.

### Polysilicon production capacity in 2007

*Breakdown per country*

(Country; Tonnes)

- **USA**: 16,560 tonnes with 4 fabs
- **China**: 8,800 tonnes with 7 fabs
- **Germany**: 8,500 tonnes with 3 fabs
- **Norway**: 6,750 tonnes with 2 fabs
- **Canada**: 1,200 tonnes with 2 fabs
- **Others**: 3,200 tonnes

**Total**: 52,160 tonnes

### Table: 2007 Production Capacity

<table>
<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>Area</th>
<th>Production capacity</th>
<th>Unit</th>
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<tr>
<td>Hemlock</td>
<td>America</td>
<td>USA</td>
<td>10,000</td>
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<td>Wacker-Chemie</td>
<td>Europe</td>
<td>Germany</td>
<td>8,000</td>
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<td>REC Silicon</td>
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<td>Norway</td>
<td>6,500</td>
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<td>Tokuyama</td>
<td>Asia</td>
<td>Japan</td>
<td>5,500</td>
<td>t</td>
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<td>MEMC</td>
<td>Europe</td>
<td>Norway</td>
<td>3,200</td>
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<td>Dow Corning</td>
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<td>Sanjing Silicon</td>
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<td>China</td>
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**Total**: 42,300 t
Production forecast
Real production
Technology breakdown

Estimated annual world production of solar cells
Breakdown by technology

<table>
<thead>
<tr>
<th>Year</th>
<th>Organic</th>
<th>DSSC</th>
<th>CdTe</th>
<th>CIS/CIGS</th>
<th>III V</th>
<th>a-Si/µ-Si</th>
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OEM have comfortable order backlogs. Their plant are fully booked until at least the end of 2008.

Some players produce diffusion furnaces for R&D labs or small fabs and want to keep this product in their portfolio: ATV Technology (Germany) for example. This kind of manufacturers produces very specific and high customized products.

Main players:
- The main players are Tempress, Centrotherm, Sierratherm, SEMCO, SVCS.
- “Others” category integrates players such as Schmid, BTU, Koyo, Sevenstar, Tecnofimes, MRL.

Share of the capacity to sell in 2008
c-Si edge isolation market in M€ from 2007 to 2012

- Laser market in M€
- Plasma market in M€
- Wet market in M€