The Competitive Cost Position of Thin Film Module Technologies In High Temperature and Low Light Conditions

IBIS Associates, Inc. is a management-consulting company that specializes in assisting clients with business development decisions in the field of advanced materials and manufacturing technologies. Founded in 1987 by students and professors of MIT’s Materials Systems Laboratory, IBIS provides economic analyses, first hand business and market intelligence in support of business development and technology strategy decisions.

The following analysis was sponsored by XsunX, a manufacturer of amorphous silicon (tandem junction) solar photovoltaic modules. All product, installation, and performance assumptions were collected from independent sources, including public literature, national laboratories, and independent system integrators.

Introduction

The Levelized Cost of Electricity (LCOE) is the principle metric by which electricity generation technologies, including solar photovoltaics are compared. This established lifecycle cost metric takes into account those aspects of a technology’s performance that directly impact power generation, system cost, and reliability. LCOE is a measure of the total lifecycle costs associated with a PV system divided by the expected lifetime-energy output, while accounting for the appropriate adjustments such as the time value of money, etc.

The National Renewable Energy Laboratory (NREL) has developed a robust model that considers environmental conditions in hundreds of US locations, and has the capacity to consider international locations. The Solar Advisory Model (SAM) also includes module performance data as verified by the independent lab for many commercially available module products.

For this analysis, five (5) key competing PV products have been chosen for comparison; representing a diverse range of available and leading PV products.

- a-Si triple junction (e.g. ECD)
- mc-Si (Schott)
- CIGs (Global Solar)
- CdTe (First Solar)
- X-Si (Sharp)
- a-Si tandem junction (XsunX)

The technologies were chosen based on their prominence in the market and unique performance characteristics.

Two (2) US locations were chosen that provide a basis for evaluating the products in extreme temperature and irradiance conditions.
• Phoenix, AZ (average temperature: 72.6 F)
• Portland, OR (annually, 50% of the time skies are at least 90% covered)

The locations were also selected based on the availability of climate and environmental data (i.e. solar radiance, cloud coverage, temperature, etc.).

**Installation Description**

Levelized Cost of Electricity (LCOE) analyses are calculated based on simulations of products and systems designs in specific locations. The module technologies under consideration may be configured in a wide range of stationary, tracking, rooftop or field installations. System design drives the Balance of System (BoS) requirements, land usage, maintenance and installation costs and performance (tracking). The purpose of this analysis is to evaluate the performance of solar photovoltaic field installations.

Typically, a field installation is sized based on the direct peak power rating of the modules, in this case: 1 MW. The realized alternating current derived from each installation is dependent upon the performance of the modules over time.

Each system was designed using the same balance of system components – inverter, rack, long/short wiring, conduit, monitoring components, etc. The installation labor rates were also held constant for each proposed module-specific system.

The number of connections, wiring, and rack content varied by module technology (product). The number of modules needed to achieve a 1MW DC-peak installation depends on the size of the modules.
Module count, in turn drives the labor required to complete the connection, and long wiring installation tasks. Module efficiency (power density) drives the land requirements (cost).

The proportion of labor and balance of system components that make up each competing module-based system design were derived from system integrator experience. Integrators who have experience building installations using one or more of the module technologies considered in this analysis were asked to compare systems. In some cases, unexpected differences were found, such as the impact of module weight on racking costs. In areas where racks are not designed for snow loads, module weight can drive rack material-content.

**Module Performance Characteristics**

IBIS Associates relied on published product literature, testing by independent laboratories, and conversations with experience system integrators to characterize these module technologies. Module pricing reflects the volume based pricing collected by systems integrators and IBIS Associates. IBIS acknowledges that some of the product pricing included here differs from the published average module pricing of some manufacturers. The pricing here depicts the pricing that a system integrator would encounter based on the channels to market that exist for purchases at 1MW volumes.

<table>
<thead>
<tr>
<th></th>
<th>mc-Si</th>
<th>a-Si (triple)</th>
<th>CuG</th>
<th>CdTe</th>
<th>X-Si</th>
<th>a-Si (tandem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_{DC \text{ peak}}$ (W)</td>
<td>300</td>
<td>135.3</td>
<td>120</td>
<td>75</td>
<td>216</td>
<td>126.4</td>
</tr>
<tr>
<td>Size (m²)</td>
<td>2.43</td>
<td>2.16</td>
<td>1.47</td>
<td>0.72</td>
<td>1.63</td>
<td>1.6</td>
</tr>
<tr>
<td>Efficiency (%)</td>
<td>12.4%</td>
<td>6.26%</td>
<td>8.2%</td>
<td>10.4%</td>
<td>12.6%</td>
<td>7.9%</td>
</tr>
<tr>
<td>$T_{derate}$ (% / °C)</td>
<td>-0.47%</td>
<td>-0.31%</td>
<td>-0.6%</td>
<td>-0.2%</td>
<td>-0.47%</td>
<td>-0.31%</td>
</tr>
<tr>
<td>Price ($/W_{DC \text{ peak}}$)</td>
<td>$3.33</td>
<td>$3.16</td>
<td>$3.50</td>
<td>$3.00</td>
<td>$3.52</td>
<td>$3.00</td>
</tr>
</tbody>
</table>

Table 1 – Key product performance characteristics, including volume-based module pricing

Module performance is often generalized by nameplate efficiency ratings, which is based on testing that is performed at Standard Test Conditions (STC). Modules are rarely installed in conditions that can be characterized as ‘Standard’. The following analysis is intended to profile the performance benefits associated with several thin film and bulk silicon technologies, some of which are regarded as ‘high efficiency’ products, and others who are often portrayed as low efficiency by comparison, but also low cost.

The true cost of ownership for these technologies must take in to account the impact of module size, temperature derate, and performance characteristics in diffuse (low) light conditions.
Figure 2 – Simulation results: tandem junction amorphous silicon module (XsunX) performance in low light (Portland, OR) and high cell-temperature (Phoenix, AZ) environments

Amorphous silicon technologies have been found to provide a performance benefit in diffuse light conditions\(^1\). Amorphous silicon devices will provide greater performance at the beginning and end of the day, as well as during cloudy conditions, such as is found in Portland, Oregon (USA).

\(^1\) “Triple Junction Thin Film Silicon Solar Cells compared to Crystalline Silicon Solar Cells under Real Outdoor Conditions in Western Europe”, Cleef et al, Bekaert ECD Solar Systems Europe N.V.- BESS EUROPE, Zulte, Belgium, 2001
Levelized Cost of Electricity Results

The simulated module performance characteristics and system installation costs were used to drive the economic (Levelized Cost of Electricity) analysis.

Module products that are relatively small in size (e.g. CdTe) require additional labor for installation. Low efficiency products require a relatively high module count, in order to achieve the target 1MW DC peak installation size. The contribution of balance of system and installation costs can be as high as 40% or more (e.g. CdTe – Figure 3b above). Module price is important, but must be considered in the context of a location specific analysis, in order to accurately benchmark product technologies.
Conclusions
The analysis demonstrates the importance of system design constraints, module performance in addition to nameplate efficiency on lifecycle system economics. The benefits associated with temperature coefficient derate characteristics are accentuated through the choice of Phoenix, Arizona as a case study location. It is expected that in other types of installations, such as rooftop mountings which are area constrained, the importance of power density (module efficiency) would become more important.
XsunX provides the core technology, embodied in our proprietary cell designs and core manufacturing systems, enabling our customers to manufacture advanced thin film solar devices on flexible or rigid substrates. We function as a strategic solar technology partner, supplying the advanced thin film solar cell manufacturing know-how and capabilities that will enable our OEM customers to address the exploding market for thin film solar products.

In addition, XsunX manufactures Solar Photovoltaic (PV) modules at its newly constructed Oregon facility that are designed to outperform in environments where other solar panels experience electrical output loss. These PV modules use two stacked layers of amorphous silicon, a proven and reliable thin film material, to achieve a stabilized efficiency of 7.9% at the module level. These modules use an aluminum frame and standard UL approved J-box, include a self tapping grounding screw, instructions, and warranty information.

XsunX, Inc.
65 Enterprise
Aliso Viejo, CA 92656
Tel 949-330-8064
Fax 949-330-8061

General Information: info@xsunx.com
Investor Information: vanessaw@xsunx.com

Alan C. Goodrich, Principal – Solar Activities, IBIS Associates, Inc.
Mr. Goodrich graduated from Rensselaer Polytechnic Institute’s Decision Science and Engineering School of Industrial and Management Engineering. While at Rensselaer, Mr. Goodrich’s project experience focused on engineering economics, the design and analysis of various work systems, as well as facility planning and plant layout for several types of manufacturing processes.

Since joining IBIS Associates, Mr. Goodrich has focused on assisting clients with business development decisions in many materials-related technology fields. His primary job responsibilities have focused on the gathering and analysis of competitive manufacturing intelligence and the design of manufacturing strategies. Alan’s diverse project experience includes the development of custom cost and market analysis in support of business development programs in the fuel cell, photovoltaic, biomedical, specialty chemical, composites, and automotive industries.

Alan is currently pursuing an MBA at Rensselaer’s Lally School of Technology Management.

IBIS Associates, Inc.
1601 Trapelo RD, Ste 164
Waltham, MA 02451
Tel: 781-290-5387
alan@ibisassociates.com