Solar PV Manufacturing
U.S. Competitiveness in a Global Industry

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Si Solar Manufacturing Supply Chain

Also...
• Capital equipment
• Raw materials
• Intermediate products


PV Module Trade Flows

Solar PV Market Developments
Global U.S. Position Ceded to China & Taiwan

Between 2000 and 2010 global shipments grew 53% (CAGR) and:

- U.S. market share has slipped from 30% to 7% (30% CAGR)
- While China/Taiwan has grown from <2% to 54% (115% CAGR)

Sources:
Meager domestic demand belies China’s dominant production

- 9.3 GW_{PDC} shipments vs. 0.5 GW_{PDC} installed
China’s Focused Growth: (4) Key Players, All Si

- Growth enabled by access to low cost debt, technology diffusion.

Sources:
• U.S. private investors encourage technology differentiation – opportunities for producers of innovative Thin Film PV technologies
• China’s government-backed investors fund more mature technologies – opportunities for w-Si technologies (quick scale-up; wages, exports)

2009 ARRA Manufacturing Tax Credit (section 48C):
- "...have the greatest potential for technological innovation and commercial deployment."

- "...employ new or significantly improved technologies as compared to commercial technologies."

- Amended EPAct § 1703; Expired September 30, 2011.

“The (Loan Guarantee) program was designed to provide support to these cutting edge industries, which have great potential to create jobs in whatever country wins the clean energy race, but also involve technology and market risks that private sector lenders often cannot or will not underwrite.”

— Jonathan Silver, Executive Director LPO, U.S. DOE

Sources: Graphic – Bloomberg NEF (4/9/10, 4/16/10, 11/8/10, & 3/16/11);
J. Silver Testimony before the Subcommittee on Oversight and Investigations Committee on Energy and Commerce, U.S. House of Representatives (September 14, 2011)
• Single junction wafer Si approaching practical performance limit.
• Challenge facing thin films: closing the gap between laboratory and production devices
TF PV technologies seek to close the gap: innovative, disruptive

- Startups raise capital based on defensible, disruptive IP position

Has U.S. focus on innovative technologies been successful?
No?

Recent Headlines – Politics and Policy:

**Solyndra Bankruptcy Reveals Dark Clouds in Solar Power Industry**

*By Anne C. Mulkern of Greenwire*

China Benefits as U.S. Solar Industry Withers

**Overrun by Chinese Rivals, U.S. Solar Company Falters**

*Business | August 17, 2011*

**Evergreen Creditors Fight Plan for Auction, Move to China**

*By Steven Church - Sep 2, 2011*

**Intel-Backed Solar Company Files for Bankruptcy as Prices Slide**

*By Andrew Hamrick and Michael Bettin - Aug 24, 2011 1:00 AM EDT*

**Veeco exits CIGS thin-film PV systems business, sees commercial timeframe, cost as unacceptable**

**China Has Won The Solar War - Now What?**

*Seeking Alpha*

[http://www.sfnblog.com](http://www.sfnblog.com)
Has U.S. focus on innovative technologies been successful? Yes?

U.S. Posted a Trade Surplus in Solar Technologies, Study Finds
By KEITH BRADSHAW

SoloPower to Expand U.S. Manufacturing Capacity to 400 MW
By TODD WOODY
Published: April 7, 2011
PRESS RELEASE
Aug. 19, 2011, 5:13 p.m. EDT

G.E. Plans to Build Largest Solar Panel Plant in U.S.

First Solar Dedicates Mesa Factory Site
Todd Spangler Appointed Site Director and General Manager

CaliSolar to Build $600 Million Polysilicon Plant in Mississippi
By Brian Goossens - Sep 6, 2011

Suntech Unveils Plans for First U.S. Factory in Goodyear, Arizona
Manufacturing Plant to be a Showcase for Latest-Generation Technologies and Equipment

SoloPower to Expand U.S. Manufacturing Capacity to 400 MW

Abound Solar Completes Financing to Expand Production Capacity
December 14, 2010, 2:16 PM EST

DuPont Snaps Up Innovalight
NEWS | SOLAR FINANCE & VC
MICHAEL KANELLOS: JULY 25, 2011

Mississippi Strikes Again: Stion to Open Manufacturing Facility
A Red State that is positively green.
MICHAEL KANELLOS: JANUARY 4, 2011
Macroeconomic Considerations
Expected Inflation by Country

Recent and Expected Inflation: by Country

Delta between U.S. and China as high as 470 bps
- China labor rates rose nearly 50% in 2010. Some expect 2011 China inflation 20%.

Sources:
- Source: www.tradingeconomics.com
- NREL private conversations with agent from leading Chinese Si PV manufacturer, January 2011
Inflation and Chinese Wages

Manufacturing Laborers, National Average

Source: National Bureau of Statistics of China, Federal Reserve Bank of St. Louis

- Jiangsu province (Suntech) +5%
- Jiangxi province (LDK) -26%
Specific market volatility measured as $\beta_{\text{Country}}$: 
- Covariance of target country index & ACWI, divided by variance of ACWI

International Investment Risk
### Other Investment Risk Considerations

<table>
<thead>
<tr>
<th>Country</th>
<th>Political and economic stability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Status, procedures, and maturity of legal system</td>
</tr>
<tr>
<td></td>
<td>Transparency of business dealings</td>
</tr>
<tr>
<td>Economic</td>
<td>Expected inflation</td>
</tr>
<tr>
<td></td>
<td>Local regulation</td>
</tr>
<tr>
<td>Currency</td>
<td>High cost and reliability of derivatives and other hedging instruments, particularly in emerging markets</td>
</tr>
<tr>
<td>Security</td>
<td>IP protection</td>
</tr>
<tr>
<td></td>
<td>Property ownership, including the ability of creditors to repossess assets</td>
</tr>
<tr>
<td>Financial</td>
<td>Interest rates</td>
</tr>
<tr>
<td></td>
<td>Insurance (business interruption)</td>
</tr>
</tbody>
</table>

Only *Economic, Financial* risks quantified in this analysis

Other factors partially considered by Global $K_E$ approach

- **Security** risk factors related to IP, property ownership particularly important (innovative startup); binary considerations
- Access to subsidized China debt generally limits foreign ownership to minority stake, e.g. Evergreen-Jiawei JV
W.A.C.C. = \[ (D/V) \times K_D \times (1 - \tau_C) \] + \[ (E/V) \times K_E \]

**Levered, Nominal Cost of Debt (K_D):**
\[ K_D = \left[ (1 + R_f) \times (1 + i) - 1 \right] + \text{leveled corporate bond spread} \]

**Levered Cost of Equity (K_E):**
\[ K_E = K_{E\text{Unlevered}} + \left[ \frac{D}{E} \times (K_{E\text{Unlevered}} - K_D) \right] \]

Where, unlevered \( K_E \) is determined by unlevering \( R_E \):
\[ R_E = (K_D \& \text{CRP}) + (\beta_{\text{Equity}} \times \text{EMRP}_{\text{Global}}) \]

**Country Risk Premium (CRP):**
\[ \text{CRP} = R_{F\text{Country}} - R_{F\text{Global}} \]

**Equity Market Risk Premium (EMRP):**
\[ \text{EMRP}_{\text{Global}} = \frac{\text{EMRP}_{\text{Country}}}{\beta_{\text{Country}}} \]

Levered corporate bond spread estimated based on current (2011) bond spreads, estimate of best (unlevered) Solar PV bond rating (BBB for established player, e.g. First Solar; CCC for this case study, e.g. startup)

\( \beta_{\text{Equity}} \) estimated based on private conversations with VCs, PE firms, banks. Solar PV industry: 2.0. Startup, e.g. company profiled in the following case study: 3.5.

Supply Side Incentives
# Manufacturing Subsidies by Country

<table>
<thead>
<tr>
<th></th>
<th>U.S. Loan Guarantee, Manufacturing Tax Credit</th>
<th>U.S. State Subsidies</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic proprietorship required?</td>
<td>Yes</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Sales/Value Added Tax waiver?</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Property tax credits</td>
<td>100%</td>
<td>100%</td>
<td>N/A</td>
</tr>
<tr>
<td>Subsidized cost of debt</td>
<td>4.0%</td>
<td>3.0%</td>
<td>3.0-4.5%</td>
</tr>
<tr>
<td>Subsidized debt limit (D/ D+E)</td>
<td>60%</td>
<td>60%</td>
<td>80%</td>
</tr>
<tr>
<td>delay in processing subsidized debt</td>
<td>2 years</td>
<td>&lt;1 year</td>
<td>&lt;1 year</td>
</tr>
<tr>
<td>Facilities grant</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land grant</td>
<td></td>
<td>Discount purchase (land use rights)</td>
<td></td>
</tr>
<tr>
<td>Training grant (millions USD)</td>
<td>$0.5-4.5</td>
<td>$0.5-4.5</td>
<td></td>
</tr>
<tr>
<td>Effective Corporate income tax rate</td>
<td>28%</td>
<td>28%</td>
<td>21%</td>
</tr>
<tr>
<td>Income tax credits</td>
<td>$0.5-4.5</td>
<td>30% MTC Cash Grant in lieu</td>
<td>State: 5-7 year holiday</td>
</tr>
</tbody>
</table>

Solar PV Module Technologies

Disaggregate supply chain
- Multiple players, some vertically integrated
- Intermediate products are relatively cheap to ship
- Wide range of automation levels
- Relatively mature, less tech. differentiation than TF PV

Many flavors of TF PV
- Many opportunities for tech. differentiation
- Monolithically integrated
  Single factory: glass & gas in, modules out
- No intermediate products (shipping costs)
- Automation does not vary, regionally
Hypothetical Case Study 1:  
China based c-Si PV manufacturer, U.S. end market.

_The case for Foreign Direct Investment._
Facility location decision:
• Regional labor costs and automation
• Shipping costs
• Inflation
• Investment risk

Competitive cost factors excluded from this case study:
• Scale – no difference in firm purchasing power
• Equipment discounts – no difference in equipment suppliers
Direct labor content varies from <1.0 job/$W_{P_{DC}}$ to 4.0 jobs/$W_{P_{DC}}$

- Suntech automation strategy (~1.4 jobs/$W_{P_{DC}}$) reflects inflation risk, not cost benefits

Relative to low cost labor regions, automation requires:

- 80% less direct labor content, 33% additional investment (automation)

Sources:
**China’s Competitive Advantage: Si Cells**

### Wafer Based Silicon Cell: Core Manufacturing Costs

14.4% standard monocrystalline cell, global wafer price: $0.50/Wp, DC.

<table>
<thead>
<tr>
<th>2011 $/US/Wp, DC</th>
<th>U.S. (80 MW plant)</th>
<th>China (80 MW plant)</th>
<th>2,000 MW plant</th>
<th>Discount equipment</th>
<th>Discount materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.75</td>
<td>$0.80</td>
<td>$0.82</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0.70</td>
<td>$0.75</td>
<td>$0.78</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0.65</td>
<td>$0.73</td>
<td>$0.73</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>$0.60</td>
<td>$0.64</td>
<td>$0.71</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0.55</td>
<td>$0.58</td>
<td>$0.68</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0.50</td>
<td>$0.55</td>
<td>$0.66</td>
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<tr>
<td>$0.45</td>
<td>$0.46</td>
<td>$0.66</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0.40</td>
<td>$0.46</td>
<td>$0.66</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0.35</td>
<td>$0.41</td>
<td>$0.66</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0.30</td>
<td>$0.41</td>
<td>$0.66</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0.25</td>
<td>$0.43</td>
<td>$0.66</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*U.S. (80 MW plant) fully automated, China (80 MW plant) fully automated, 2,000 MW plant No automation.*

- **China**: 18-20% core cost advantage

### Sources:


National average labor rates assumed for U.S., China scenarios. “Discount materials”: 10%.

“Discount equipment”: 50% for wet benches, screen printer lines, co-firing furnace operations only.

“Core Costs” include direct labor, materials, energy, depreciation expenses, but exclude: shipping costs, cost of capital, taxes.
Si Module Shipping Costs

- Costs including fees, insurance are significant, total: \( \sim \)$0.05/W_{P\,DC} 
- Cost of capital excluded (Shanghai to Los Angeles: 30 day transit time) 
- Cost of breakage excluded 
- Shanghai to Hamburg, Newark to Hamburg costs roughly the same

Regional Benchmarking Analysis:
Direct Si PV Module Core Costs

Benchmark regional costs (unsubsidized), including shipping costs to Phoenix, AZ customer
[Port of entry for sea shipping: Los Angeles, CA. U.S. production location: Goodyear, AZ]

- China-direct manufacturing cost benefits, excluding shipping: 1-2%
- Including shipping to U.S., China suffers a 5% cost disadvantage

Above Direct Costs analysis excludes other regional factors:
Direct government subsidies, income taxes, global economic instability (inflation), investment risk factors

Maersk online cost estimating tool (accessed March 2011). NREL internal shipping cost model.
### Cost of Capital (Global CAPM)

<table>
<thead>
<tr>
<th>Facility location</th>
<th>Subsidy program, if any.</th>
<th>U.S. Loan Guarantee (LG)</th>
<th>U.S. LG, 30% MTC grant</th>
<th>U.S. State Subsidies</th>
<th>China Subsidized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debt percent (book D / book V)</td>
<td>60%</td>
<td>60%</td>
<td>60%</td>
<td>60%</td>
<td>60%</td>
</tr>
<tr>
<td>Real cost of Debt ($K_{D, Real}$)</td>
<td>6.4% (BB-)</td>
<td>4.0%</td>
<td>4.0%</td>
<td>3.0%</td>
<td>10.2% (BB-)</td>
</tr>
<tr>
<td>Loan Terms</td>
<td>2 year delay, $2.5 million application costs</td>
<td>2 year delay, $2.5 million application costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected Inflation (i)</td>
<td>3.6%</td>
<td>6.5%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal Cost of Debt ($K_{D, nominal}$)</td>
<td>10.0%</td>
<td>7.7%</td>
<td>7.7%</td>
<td>6.7%</td>
<td>17.0%</td>
</tr>
<tr>
<td>Expected Market Return ($R_m$)</td>
<td>10.8%</td>
<td>18.1%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country Beta ($\beta_{country}$)</td>
<td>0.91</td>
<td>1.34</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal EMRPGlobal</td>
<td>7.0%</td>
<td>5.0%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Company’s Equity Beta ($\beta_{E Company}$)</td>
<td>3.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Levered (Global) Cost of Equity ($K_{E, Levered}$)</td>
<td>25.8%</td>
<td>25.8%</td>
<td>25.8%</td>
<td>25.8%</td>
<td>35.4%</td>
</tr>
<tr>
<td>Corporate Tax Rate ($T_C$)</td>
<td>28%</td>
<td>28%</td>
<td>28%</td>
<td>28%</td>
<td>21%</td>
</tr>
<tr>
<td>Global CAPM (WACC) / Hurdle Rate</td>
<td>14.6%</td>
<td>13.7%</td>
<td>13.7%</td>
<td>13.2%</td>
<td>22.2%</td>
</tr>
</tbody>
</table>

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1. Based on Suntech Corporation book value of total debt divided by book value of total assets (as of 10/06/11).
2. 30% Manufacturing Tax Credit (MTC) monetized in year 1, effectively reducing depreciation expenses.
4. U.S. LG award delay: 2 years; application cost: $2.5 million; Low cost China debt subsidized based on condition that foreign ownership is limited to minority stake (≤49%)
5. Average rate of inflation (i) since Jan-2008 for U.S. and China, as reported by “Trading Economics” (www.tradingeconomics.com).
6. Based on Fisher equation: $K_{D, nominal} = (1 + KD_{real})(1 + i) – 1$
7. Expected market return ($R_{m, U.S}$); S&P 500; 50 years: 1961 to present (September 2011).
8. Expected market return ($R_{m, China}$); MSCI AWCI Broad China
9. Country Beta ($\beta_{country}$) = Covariance (Country Index, MSCI AWCI)/ Variance (MSCI AWCI)
10. Company’s Equity Beta ($\beta_{E Company}$) based on Suntech Corporation, as reported by yahoo.finance.com (10/6/11)
11. Levered (Global) Cost of Equity ($K_{E, Levered}$) = $K_{E, Unlevered} + \left[\left(D/E\right)\left(K_{E, Unlevered} - KD_{nominal}\right)\right]$
14. 20 year China corporate tax holiday
16. Global CAPM (WACC) / Hurdle Rate = $\left[\frac{E(V)}{E(V)+D}(K_{E, Levered})\right] + \left[\frac{D}{E(V)}KD_{nominal}\right][(1 - T_C)]$
Regional Benchmarking Analysis: Minimum Sustainable Si PV Module Price

Chinese Si PV manufacturers should consider regional module production strategy
• Regional module manufacturing facilities located near end market reduce glass shipping costs, mitigate impact of China’s inflation on product costs.

NREL internal DCF (2011), including Global CAPM analysis and country based incentives (private conversations with PV companies)
Hypothetical Case Study 2:
U.S. thin film (CIGS) PV startup, U.S. end market.

*Capitalizing on U.S. innovation.*
CIGS Module Shipping Costs

- Costs including fees, insurance are significant, total: \(~$0.05/W_{P\text{DC}}\)
- Cost of capital excluded (Shanghai to Los Angeles: 30 day transit time)
- Cost of breakage excluded
- Shanghai to Hamburg, Newark to Hamburg costs roughly the same

Sources:
- Maersk online shipping calculator, NREL private conversation with Maersk sales representatives. 2011
- Bunker Adjustment Factor as of (March 31, 2011)
- Fuel surcharge based on $3.96-$3.99/gallon gas price. Average DOE diesel fuel surcharge. (March 2011)
Regional CIGS Module Costs

CIGS Trunkey Production Line, Courtesy: Centrotherm

<table>
<thead>
<tr>
<th>600 MW_{PDC} CIGS Module Facility (near term target module efficiency = 16.6%)</th>
<th>US</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Direct Laborers (all shifts)</td>
<td>540</td>
<td>540</td>
</tr>
<tr>
<td>Unskilled Labor rate ($ per hour)</td>
<td>$13.33</td>
<td>$2.13</td>
</tr>
<tr>
<td>Manufacturing Engineer ($ per year)</td>
<td>$75,110</td>
<td>$8,171</td>
</tr>
<tr>
<td>Total facility Capex ($/W_p)</td>
<td>$0.40</td>
<td>$0.33</td>
</tr>
</tbody>
</table>

First Solar (Copy Smart\textsuperscript{TM}):
- Vietnam (2H 2011) facility
  $300MM, 600 jobs / 250 MW_{PDC} capacity
  [http://compoundsemiconductor.net](http://compoundsemiconductor.net)
- Mesa, AZ U.S. (3Q 2012) facility
  $300MM, 600 jobs / 250 MW_{PDC} capacity
  [http://www.brighterenergy.org](http://www.brighterenergy.org)

CIGS direct labor content assumed not to vary by region: ~0.9 job/MW\textsubscript{PDC}

Sources:
Regional Benchmarking Analysis:
Direct CIGS PV Module Core Costs

- China-direct manufacturing cost benefits, excluding shipping: 10%
- Including shipping to U.S., China advantage reduced to -3%

Above Direct Costs analysis excludes other regional factors:
Direct government subsidies, income taxes, global economic instability (inflation), investment risk factors

Sources:
Maersk online cost estimating too (accessed March 2011). NREL internal shipping cost model.
### Cost of Capital (Global CAPM)

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<th>China</th>
<th>China Subsidized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debt percent (book D / book V)³</td>
<td>65%</td>
<td>60%</td>
<td>60%</td>
<td>60%</td>
<td>50%</td>
<td>80%</td>
</tr>
<tr>
<td>Real cost of Debt (Kₚₐₚₑₚ Real)³</td>
<td>8.9% (B)</td>
<td>4.0%</td>
<td>4.0%</td>
<td>3.0%</td>
<td>9.5% (B)</td>
<td>3.0%¹³</td>
</tr>
<tr>
<td>Loan Terms⁴</td>
<td></td>
<td>2 year delay, $2.5 million application costs</td>
<td>2 year delay, $2.5 million application costs</td>
<td>Foreign ownership limited to minority stake</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected Inflation (i)⁵</td>
<td></td>
<td>3.6%</td>
<td></td>
<td></td>
<td>6.5%</td>
<td></td>
</tr>
<tr>
<td>Nominal Cost of Debt (Kₚₐₚₑₚ nominal)⁶</td>
<td>12.5%</td>
<td>7.7%</td>
<td>7.7%</td>
<td>6.7%</td>
<td>16.3%</td>
<td>11.6%</td>
</tr>
<tr>
<td>Expected Market Return (Rₚₐₚₑₚ)⁷</td>
<td></td>
<td>10.8%</td>
<td></td>
<td></td>
<td>18.1%³</td>
<td></td>
</tr>
<tr>
<td>Country Beta (βₚₐₚₑₚ)⁹</td>
<td></td>
<td>0.91</td>
<td></td>
<td></td>
<td>1.34</td>
<td></td>
</tr>
<tr>
<td>Nominal EMRPₚₐₚₑₚ Global¹⁰</td>
<td></td>
<td>7.0%</td>
<td></td>
<td></td>
<td>5.0%</td>
<td></td>
</tr>
<tr>
<td>Company’s Equity Beta (βₚₐₚₑₚ)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.5¹¹</td>
<td></td>
</tr>
<tr>
<td>Levered (Global) Cost of Equity (Kₚₐₚₑₚ Levered)¹²</td>
<td>28.3%</td>
<td>27.5%</td>
<td>27.5%</td>
<td>27.5%</td>
<td>35.8%</td>
<td>57.2%</td>
</tr>
<tr>
<td>Corporate Tax Rate (Tₚₐₚₑₚ)¹⁵</td>
<td></td>
<td>28%</td>
<td>28%</td>
<td>28%</td>
<td>21%</td>
<td>0%¹⁴</td>
</tr>
<tr>
<td>Global CAPM (WACC) / Hurdle Rate:¹⁶</td>
<td></td>
<td>15.8%</td>
<td>14.3%</td>
<td>14.3%</td>
<td>13.9%</td>
<td>24.4%</td>
</tr>
</tbody>
</table>

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2. 30% Manufacturing Tax Credit (MTC) monetized in year 1, effectively reducing depreciation expenses.
4. U.S. LG award delay: 2 years, application cost: $2.5 million); Low cost China debt subsidized based on condition that foreign ownership is limited to minority stake (≤49%)
5. Average rate of inflation (i) since Jan-2008 for U.S. and China, as reported by “Trading Economics” (www.tradingeconomics.com)
6. Based on Fisher equation: KD nominal = (1 + KD real)*(1 + i) – 1
8. Expected market return (R_e China): MSCI AWCI Broad China
9. Country Beta (βₑ country) = Covariance (Country Index, MSCI AWCI) / Variance (MSCI AWCI)
10. Nominal Equity Market Risk Premium (EMRP) = (R_m – KD nominal)/βₑ country
11. Company’s Equity Beta (βₑ company) based on Suntech Corporation, as reported by yahoo.finance.com (10/6/11)
12. KE Levered = KE Unlevered + [(D/E)*(KE Unlevered – KD nominal)]
13. Based on anecdotal information from startup PV firms who are investigating global production locations.
14. 20 year China corporate tax holiday
16. WACC = [(E/V)*KE Levered] + [(D/V)*KD nominal*(1 – TC)]
Over past 2-3 years, “U.S.” (unsubsidized) case has largely been unavailable to innovative thin film startups. Access to capital in U.S. must be expanded.

Summary

• China is the world’s leader in global production (55% market share)
  • 95% of production is exported; no domestic demand
• The U.S. is a leader in early stage technology investments that have disruptive potential
• Shipping costs offset China’s core cost advantage
  • c-Si module advantage reduced from 1% to -5%
  • CIGS advantage reduced from 10% to -3%
• Access to low cost capital is needed to offset investment risk in emerging markets
  • Cost of capital: China (25%) with subsidy (20%), vs. U.S. (16%)
  • Inflation and changes in value of currency are significant
Conclusions

• China advantage may not be sustainable
  • Inflation
  • Growing importance of shipping costs
  • Reliance on massive government subsidies
  • Lack of technology diversification
    • Risk of being supplanted by disruptive non-Si technology

• U.S. incentives can level the playing field
  • The scale of Chinese incentives dwarf U.S. efforts
  • Access to capital is a critical compliment to the U.S.’ capacity to innovate
Comparative advantages

- Low cost electricity (hydro power and poly Si)
- Complimentary industries
  - Specialty chemicals, non-woven films (Dow, DuPont, 3m, Eastman Chemical, etc.)
- Institutional capacity for R&D (innovation)
- Private capital
- Demand potential

Risk factors

- Material resource availability
- Policy uncertainty (R&D funding, industrial incentives)
- Inflation
Appendix
Domestic Demand, Production

U.S. manufacturing generally reflects U.S. demand
- China and EU domestic production: demand ratios appear unsustainable

Sources: Production, GTM Research; Demand, Global Market Outlook for PV until 2015 (EPIA 2010)
PV Manufacturing vs. VC/PE

- U.S. leads world in early stage investments, but lacks follow through (mfg)
- Private capital investments in China PV market contradict that industry’s scale

Sources: BNEF: VC&PE (9/07/11); Manufacturing (9/14/11)
Solar PV Module Price Learning Curve:
Leading PV Technologies (Crystalline Silicon and Cadmium Telluride)
Sources: Navigant Consulting, Bloomberg NEF, First Solar financial filings

Global Average Module Price (2009 $US/ Wp)
CIGS cost reduction opportunities

CIGS Solar PV Manufacturing Costs:
Coevaporation (framed) on-glass cost reduction road map, U.S. production location

2011 $US/W, dc

- $1.11
- $0.63
- $0.47
- $0.40

2011 12%
Near term 17.60%
Midterm 19.90%
Longer term potential 20.50%

Interest
Energy
Labor
Maintenance
Depreciation
Module mats
Emitter + TCO
CIGS
Mo
Glass
Price
c-Si cost reduction opportunities

<table>
<thead>
<tr>
<th>Technology Group 1</th>
<th>Technology Group 2</th>
<th>Technology Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>180 µm wafer</td>
<td>120 µm wafer</td>
<td>80 µm wafer</td>
</tr>
<tr>
<td>140 µm kerf</td>
<td>90 µm kerf</td>
<td>kerfless</td>
</tr>
<tr>
<td>Selective emitters</td>
<td>All rear contacts</td>
<td>Ultrathin, All rear contacts</td>
</tr>
<tr>
<td>14.4% modules</td>
<td>21.5% modules</td>
<td>21.5% modules</td>
</tr>
</tbody>
</table>

- Selective Emitters:
  - PS: $34/kg
  - 10 Cz recharges
  - 80 micron Ag
  - Frameless module

- All Rear Contacts:
  - PS: $33/kg
  - 10 Cz recharges
  - 40 micron Ag see+ CuAgSn plating
  - Enhanced passivation (dielectric)
  - Rear point contacts
  - AR glass

- Ultrathin/Kerfless:
  - PS: $32/kg
  - Ni electroless seed
  - All Cu emitter (plating)
• Significant opportunities exist in TF PV to close the gaps between theoretical and laboratory; laboratory and commercial devices
Efficiency adjusted module prices

Residential rooftop: efficiency matters (area constrained)

Capital analysis excludes consideration of capacity factor differences due to tracking, temperature coefficient, diffuse light performance, etc.

Current, Forecast Solar PV Module Costs

Prices based on uniform minimum sustainable 20% gross margin

*Efficiency penalty refers to impact of select module efficiency on system price relative to baseline (19.6% module).

Efficiency adjusted module prices

Utility scale: room for lower efficiency to compete
Capital analysis excludes consideration of capacity factor differences due to tracking, temperature coefficient, diffuse light performance, etc.

Current, Forecast Solar PV Module Costs
Prices based on uniform minimum sustainable 20% gross margin

*Efficiency penalty refers to impact of select module efficiency on system price relative to baseline (19.6% module, one axis tracking).