Methods

To benchmark the two regions of interest and understand drivers of the photovoltaic (PV) industry's regionalization of manufacturing over the past decade, we establish, from the bottom-up, the direct production costs and long-term competitive prices for crystalline silicon (c-Si) products made by a hypothetical, representative factory in each region.[1-4]

Technical Cost Models

The manufacture of c-Si modules involves many process steps and a disaggregated supply chain; modules are composed of cells, which are made using wafers. For each discrete step in the production of these components, we consider material, direct and overhead labor, energy, fixed-capital, and capital-maintenance costs incurred by a manufacturing firm.[2-4] Because of the relative maturity of the c-Si technology, a great deal of data is available from literature, published resources, and interviews with material and equipment vendors, all of which facilitate the development of detailed cost-model simulations (see S2, Supporting Table; S3 Validation Table; and references[2,4] for key assumptions). Industry stakeholders, SEC filings, and other market reports provide us with a top-down perspective that is useful for validating the bottom-up results (S3, Validation Table).

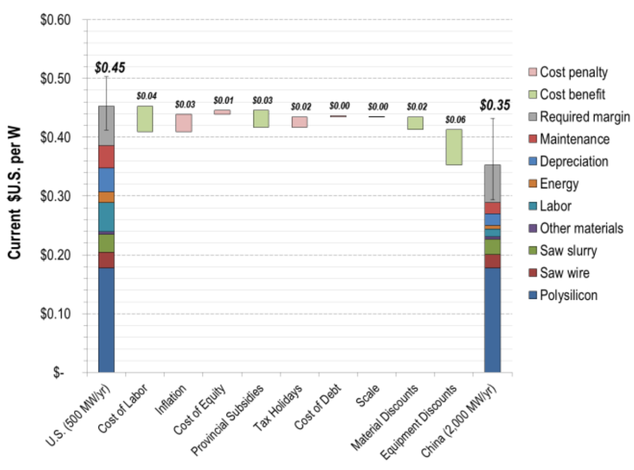


Fig. 1 Current Regional Ingot and Wafer Costs and Prices: 1H 2012 c-Si ingot and wafer direct-manufacturing costs and minimum-sustainable margins.[2]

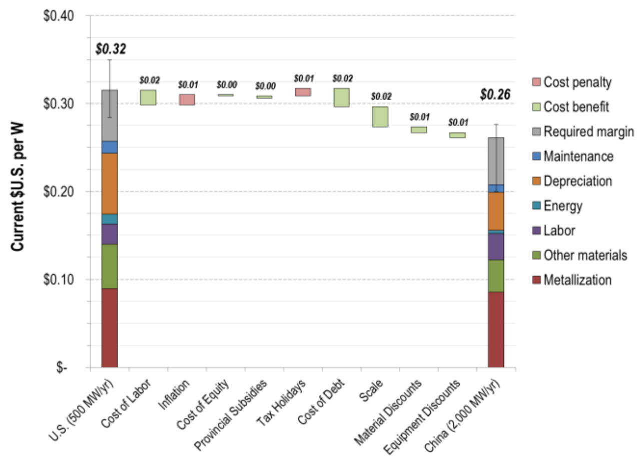


Fig. 2 Current Regional Cell Costs and Prices: 1H 2012 c-Si cell direct-manufacturing costs and sustainable margins, as modeled.[2]

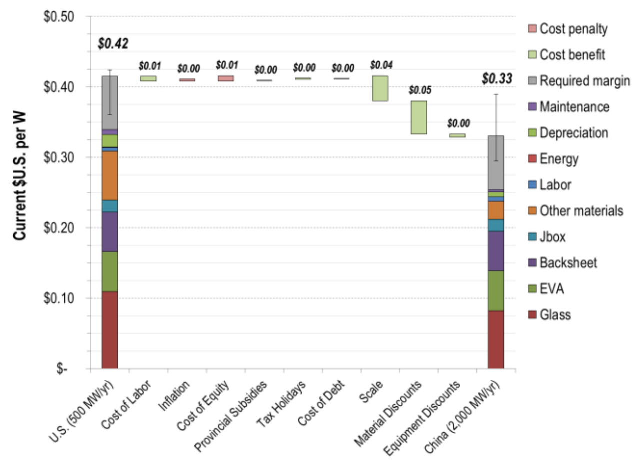


Fig. 3 Current Regional Module Costs and Prices: 1H 2012 c-Si module direct-manufacturing costs and sustainable margins, as modeled.[2]

By parameterizing from the bottom-up the direct manufacturing costs for c-Si PV, it is possible to consider differences in regional-cost factors like labor and energy. This approach further allows us to reflect on the impact that differences in factory scale, automation, and regional supply chains may have on the costs of producing c-Si products. Other parameters that may not have an immediate impact on costs, such as inflation and taxes, or that will affect price (margin requirements) require the examination of cost be extended to include a discounted free cash flow (DFCF) analysis.[2-5,14]

Supporting Materials (S1): A.C. Goodrich, D.M. Powell, T.L. James, M. Woodhouse, and T. Buonassisi, *Energy Environ. Sci.*, 2013, DOI: 10.1039/c3ee40701b

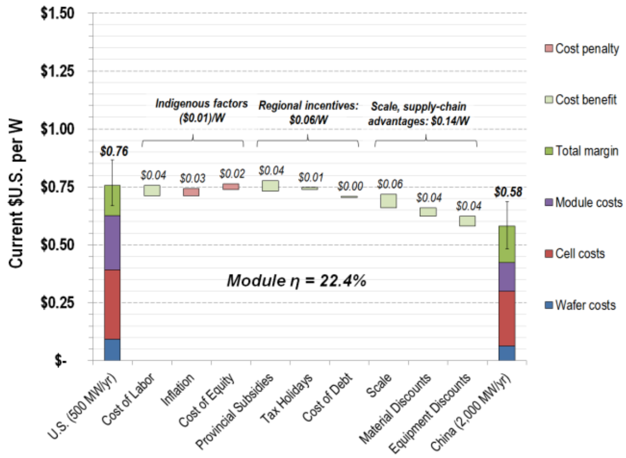
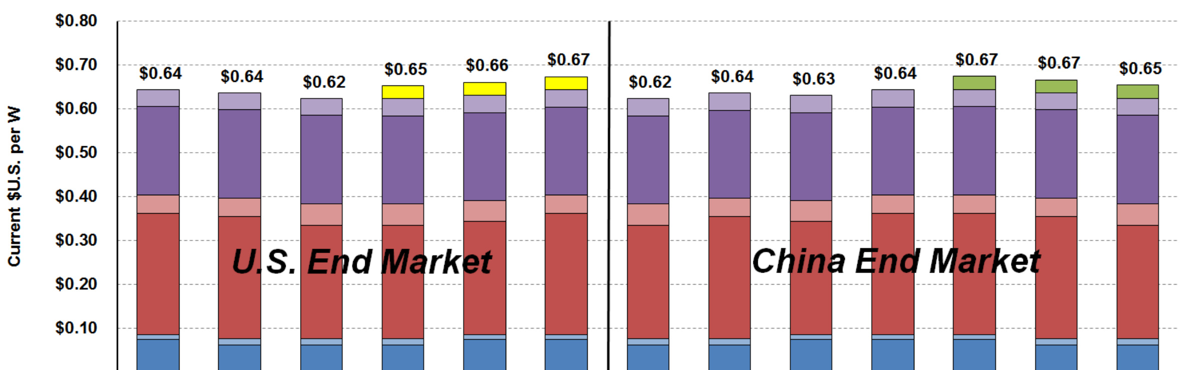


Fig. 4 Expected (Advanced Technology Scenario) Regional Module Costs and Prices, Assuming Current Differentiated Levels of Incentives and Scale Persist: Assuming that current differentiated levels of regional incentives and scale-based supply-chain advantages continue, the China-based factory maintains a significant price advantage (23%), even as advanced technological innovations are implemented in both locations. However, the dramatic reduction in overall minimum sustainable price may enable subsidy-free adoption in a wider range of markets and improved access to capital for manufacturers in both locations.

We evaluate regional manufacturing MSP and shipping prices by manufacturing step (polysilicon, wafer, cell, module) (Fig. 1-Fig. 3). Recall from the section of the manuscript entitled: *Module Shipping Costs* that the shipping costs of wafers and cells are negligible, while shipping costs of modules amounts to \$0.035/W to \$0.04/W from the U.S. to China and from China to the U.S., respectively for standard technology, and approximately \$0.03/W for the advanced technology scenario (Tables 1 and 2). As a proportion of delivered-module price, shipping costs increase as technology improves and cost per unit area is reduced (Fig. 5).



Modules	U.S.	U.S.	U.S.	China	China	China	China	China	China	China	U.S.	U.S.	U.S.
Cells	U.S.	U.S.	China	China	China	U.S.	China	U.S.	China	U.S.	U.S.	U.S.	China
Wafers	U.S.	China	China	China	U.S.	U.S.	China	China	U.S.	U.S.	U.S.	China	China
Shipping (to U.S.)	$-	$-	$-	$0.03	$0.03	$0.03	$-	$-	$-	$-	$-	$-	$-
Shipping (to China)	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-	$0.03	$0.03	$0.03
Module margin	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04
Module costs	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20	$0.20
Cell margin	$0.04	$0.04	$0.05	$0.05	$0.05	$0.04	$0.05	$0.04	$0.05	$0.04	$0.04	$0.04	$0.05
Cell costs	$0.28	$0.28	$0.26	$0.26	$0.26	$0.28	$0.26	$0.28	$0.26	$0.28	$0.28	$0.28	$0.26
Wafer margin	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
Wafer costs	$0.07	$0.06	$0.06	$0.06	$0.07	$0.07	$0.06	$0.06	$0.07	$0.07	$0.07	$0.06	$0.06
Price, net shipping	$0.64	$0.64	$0.62	$0.65	$0.66	$0.67	$0.62	$0.64	$0.63	$0.64	$0.67	$0.67	$0.65

Fig. 5 Benchmarking Alternative Regional Supply-Chain Strategies for the Advanced Technology Scenario: In the long-run, module shipping costs can outweigh the benefits of manufacturing glass c-Si PV modules for export to overseas markets.

Minimum Sustainable Pricing Methodology

The long-term competitive prices for each of the intermediate components (wafers and cells) and final products (c-Si modules) are estimated using a pro forma income statement and discounted free cash flow (DFCF) approach.[2-5,14] While the cost model is based on a bottom-up methodology that sums all relevant input factors for each discrete manufacturing step, the results are rigorously validated against a variety of top-down results available from public companies, and through private conversations with individual companies (S3, Validation Table). For each manufacturing operation, the cost model determines the number of machines required for a desired factory output based on yield and throughput assumptions. Regional differences in automation, auxiliary equipment requirements, and equipment-installation costs are used along with the station count to establish the factory-investment requirements. Importantly, the capital-investment requirements for factories in each region are differentiated based on both the relative costs of construction labor, and speed of factory construction—a factor in the cash flow, which may reflect differences in regulations that affect the scale up of industrial facilities. The cost model, likewise establishes the cost of goods sold, including materials, direct labor, and energy, with considerations for regional differences in these parameters. Certain elements of operating expenses are ascertained from the technical cost model results, including the depreciation basis, working capital requirements, and overhead (salaried) manufacturing labor expenses. The balance of operating expenses is derived from the annual operating reports of leading c-Si PV companies in both regions using a percentage-sales (revenues) method and includes the categories of sales, general, and administrative (SG&A); R&D; regulatory; and warranty expenses. Interest expenses are excluded from the cash flow to be consistent with the discount factor, which is based on the total cost of capital, including service to both debt holders and equity owners.[5,14]

In a free market, a private company's cost of debt is set by a central government's borrowing rate and a spread, determined by private lenders, reflecting the exposure of financial institutions to inflationary, company-specific, and market-risk elements. In some cases, governments can influence borrowing rates for preferred industries by, for example, subsidizing a lender's risk through loan guarantees or making direct-government loans. As we discuss later, we estimate that the cost of debt for leading Chinese PV companies has been artificially low (Fig. 6); thus, the industry receives preferentially low-cost capital. In real terms, the rates on several loans made to Chinese PV companies were below the rate of inflation. This may be due to societal objectives[6] for an industry discussed in China's 12th Five Year Plan.[7] With wage inflation as high as 20% per year, the importance of industries that offer higher-paying jobs is clear.[8]

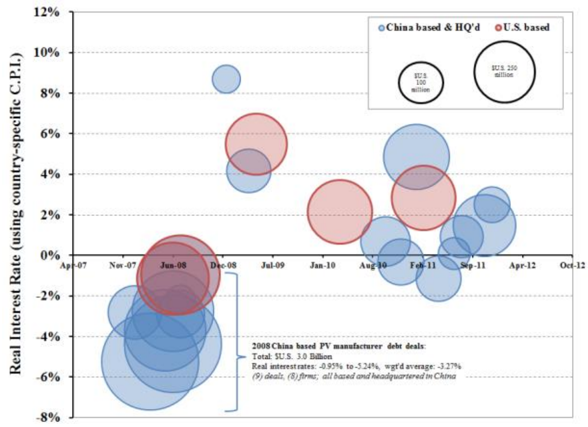


Fig. 6 Reported Solar PV Manufacturing Debt: Access to low-cost debt at a time when most global-capital markets were frozen may have contributed to China's ability to scale-up its c-Si PV Industry.[9,11]

Of particular importance to this regional-benchmarking analysis is the impact of expected inflation on the firm's margin requirements (price). While we contrast the observed real cost of debt for manufacturers in each region by excluding regional inflation, for the purposes of establishing the long-term competitive price we conduct a nominal-DFCF analysis.[5,12,13,14] Two rates of inflation are relevant to this study: the region-specific rate and the expected-global rate. The global rate affects shipping costs and the sales prices of finished goods and commodity materials, while the regional rate affects regional inputs including labor, energy, and maintenance costs.

To forecast the regional rates of inflation for the U.S. and China, we use recently reported (monthly) Consumer Price Index (CPI) figures for each country.[9] As a benchmark for the global rate of inflation, we rely on the expected figure for a developed country that is also a member of the Organization for Economic Cooperation and Development (OECD)—the U.S.

The pro forma income statement is carried through the depreciable life of the equipment (project life, including a terminal value) and used to establish a free cash flow, the total present worth of which is calculated using a discount rate equal to the nominal weighted average cost of capital (WACC).[5,14] In the long term, we assume the PV industry will reach a market equilibrium, in which case the market-clearing prices for products will be established as the price at which the sum of the discounted free cash flow equals the capital outlay, thus providing investors with returns that match expectations.[5,14] For all intermediate products, the competitive price is used to estimate the intra-firm transfer price for vertically integrated manufacturers—price becomes an input-material cost to the subsequent manufacturing activity.

While some have argued that intra-firm transfer prices are often very different from the arm's length transactions found in a disaggregated supply chain (inter-firm prices), where traditional pricing theory applies, we assume that transfer prices between

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business units within a firm must match market-based competitive prices.[14,15] If one business unit of a vertically integrated manufacturer chooses to sell its intermediate product to a sister business unit of the same firm for a price that is below the competitive (market) price, for example to maximize joint rather than individual profits, then that business unit and firm will incur an opportunity cost.

Generally, forecasted cash flows ignore many potential downside events, resulting in an upwards or optimistic bias. In industrial practice, it is most common to use a higher-than-market cost of capital, or discount factor, to translate these forecasts into expected cash flows.[10,16] Alternatively, or in addition, the probabilities of downside events may be used to adjust forecasted cash flows, but, without empirical data for such events, adding such probabilities arguably does not improve the accuracy of the results.[16] Without accounting for potential downsides to the cash flow, either by assigning probabilities to such forecasts or relying on a market-based cost of capital, expected cash flows would be upwardly biased, potentially skewing project portfolios towards risk. For example, in the context of this regional-benchmarking analysis, without considering the regional risk factors that accompany the move to a low-cost-labor location (*i.e.*, without assigning a risk-adjusted discount rate), capital budgeting decisions would gravitate to the lowest-cost locations.[17] As a result, c-Si manufacturing would chase the lowest-cost labor like that commonly found in emerging and frontier markets, despite the potential downsides of doing so. The country-specific equity market risk premium (EMRP) accounts for country-specific downside scenarios, such as societal instability, property-ownership limitations, intellectual property (IP) protection, transparency of business dealings, and corruption.[18] The sector-risk premium accounts for industry-specific risk factors such as regulatory uncertainty and historical success of other firms in the industry.

To account for the impact of regional-risk factors, such as the political and economic stability of these regions, we estimated regional discount rates using the *International Capital Asset Pricing Model*.[18,19]

In this analysis, the discount rate, or WACC, is based on three primary assumptions: company gearing or leverage, the cost of debt, and the cost of equity:

$$WACC = \omega_D \times K_D \times (1 - \tau_C) + \omega_E \times K_E \qquad [1]$$

In this formula (Equation 1), the leverage ratio (ω_D) is based on the ratio of the book value of all debt to the total value of all corporate assets, where the value of all assets is defined as the sum of the book value of all debt and the market value of equity; the ratio of equity (ω_E) being equal to one minus the leverage ratio (ω_D). The cost of debt (K_D) is based on recent (since January 2008) debt deals for major PV firms based in the U.S. and China.[11] The corporate income tax rates (τ_C) for each region are based on the mean effective rate for the U.S. and reported effective rates for Chinese PV firms.[20,21] A firm's cost of equity (K_E) is not reported and, therefore, requires several additional calculations.

First, we establish the cost of equity (K_E) based on the generally accepted method of using a risk-free rate (R_f), plus an equity market risk premium ($EMRP_{Target\ Country}$), which represents the opportunity cost for global equity investors over perceived riskless investments, *e.g.*, government bonds.[*]

$$K_E = R_f + \beta_{E,re-levered} \times EMRP_{Target\ Country} \qquad [2]$$

The risk premium is adjusted for sectoral (i.e., PV market) and company-specific (e.g., leverage) factors. These adjustments are commonly referred to as components of the equity beta ($\beta_{E,}$). We establish the sectoral equity-risk adjustment for PV by comparing the monthly returns for U.S.-based PV companies to the monthly returns of the global equity market.[21,†] In estimating sectoral risk, it is important to exclude country-risk factors; therefore, monthly stock returns from firms located in a developed OECD member country, in this case the U.S., are used because of the relative stability of the U.S. economy and lack of political risk there.[18]

$$\beta_{E,levered} = \frac{Covariance\ (U.S.-based\ PV\ firms)}{Variance\ (global\ stock\ index)} \qquad [3]$$

Using this formula and the typical leverage ratio for a publicly traded U.S.-based PV firm, one can calculate an unlevered-equity beta that is specific to the PV sector:[‡]

$$\beta_{E,unlevered} = \frac{\beta_{E,Levered}}{1 + \left((1 - \tau_C) * \frac{\omega_D}{\omega_E}\right)} \qquad [4]$$

This risk adjustment factor may then be re-levered, as required, to model a firm's specific cost of equity based on the target firm's choice of capital structure (leverage).

Having established a sectoral-risk adjustment for PV, it is now necessary to establish the global equity market risk premium ($EMRP_{Global}$). This is accomplished by first estimating the EMRP for a specific country:

$$EMRP_{U.S.} = R_m - R_f \qquad [5]$$

For the U.S., the market return (R_m) is based on the historic (since 1969) monthly returns of U.S. stocks and, correspondingly, the risk-free rate (R_f) is based on the yield for the ten-year U.S.

[*] Risk-free rate: yield on 10-year U.S. treasury, a relatively risk-free instrument that investors in all parts of the world have an equal opportunity to purchase.
[†] Monthly returns, SunPower (SPWR) and First Solar (FSLR), June 2008-February 2012, source: finance.yahoo.com, last accessed: February 29, 2012.
[‡] Based on SunPower Corporation (SPWR) leverage ratio, source: finance.yahoo.com, last accessed March 12, 2012.

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treasury.[§,**] It is then possible to calculate the global EMRP ($EMRP_{Global}$) using the following equation:

$$EMRP_{Global} = \frac{EMRP_{U.S.}}{\beta_{U.S.}} \quad [6]$$

Where the country-specific risk ($\beta_{U.S.}$) is established using a variation of the equity-beta calculation (Equation 3) that relies on the monthly market returns for the U.S. stock indices, and can easily be modified to estimate the returns for indices based in other regions: equations 3, and 4.

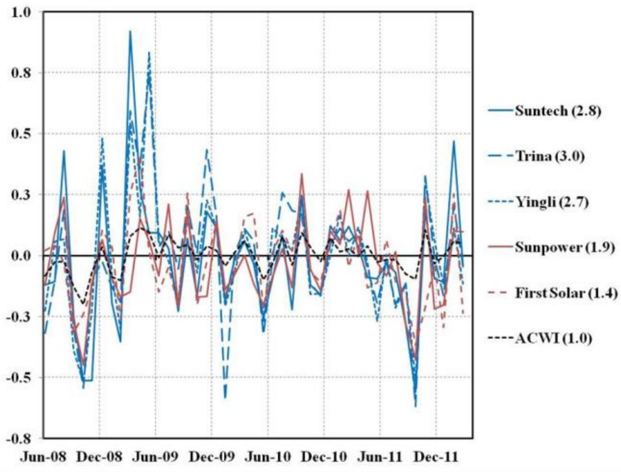
$$\beta_{U.S.} = \frac{Covariance\ (MS\ U.S.\text{–}Standard\ Index)}{Variance\ (MS\ ACWI\ Index)} \quad [7]$$

This approach can also be used to establish the country-risk premium for other countries of interest, e.g., China, using average returns for that country's leading equity index and the world index to establish a country-beta adjustment, which can then be used, along with the previously established $EMRP_{Global}$, to calculate China's country-risk adjustment ($EMRP_{China}$). For China, however, owing to the restrictions on foreign investment and the prevalence of state-owned enterprises, there is a more limited selection of stock indices available to global, rather than domestic, or preferred, equity investors (Table 6).

Certain stocks (China A) are limited to domestic investors and certain institutional investors. The China-broad market index includes stocks that are not available to global investors, so called "A-caps," as well as state-controlled enterprises ("Red Chips").[††] The Zhong Hua Overseas Index includes all stocks available to overseas (global) investors: H, B, Red Chip, P Chip, and those listed on the Hong Kong Stock Exchange. Therefore, from a global investor's perspective, the volatility of the Zhong Hua Overseas Index arguably most closely approximates the volatility of China's broad equity markets.

The China P Chip index includes companies that are listed on foreign exchanges, like the Hong Kong Stock Exchange, and are incorporated in the Cayman Islands, Bermuda, and the British Virgin Islands with operations in mainland China but run by private-sector Chinese businessmen. During the financial crisis of 2007–2010, P Chips showed a dramatic increase in the rate of bankruptcy failures compared with H Shares or Red Chips. The China P Chip Index best approximates leading Chinese c-Si companies—such as Suntech, Trina, Yingli, JA Solar, and Jinko Solar—which are all incorporated in the Cayman Islands but have operating subsidiaries incorporated in China and are traded on a foreign exchange, *e.g.*, the New York Stock Exchange (NYSE).

Rather than relying on one Chinese stock index, we have chosen instead to estimate the global market's perception of China-based country risk by comparing the historic returns of Chinese- and U.S.-based PV firms (Table 6 and Table 7). Because more than 99% of all manufacturing activities conducted by companies with either Chinese-manufacturing or a China-based corporate headquarters occur domestically, we conclude it is accurate to use these firms as a measure of global equity investor sentiment towards Chinese investments, *i.e.* to estimate China-country risk.[23] So called "U.S. PV firms," on the other hand, may be headquartered in the U.S., but conduct a majority (more than 90%) of manufacturing operations offshore. In the eyes of global equity investors, we assume such companies are viewed as being global. By normalizing the returns of U.S.- and China-based PV firms for leverage and sectoral (market) risk factors, one can establish the premium that is attributable by global-equity investors to China country risk.



	Suntech	Trina	Yingli	Sunpower	First Solar
$\beta_{E,L}$	2.8	3.0	2.7	1.9	1.4
$\beta_{E,UL}$	1.4	1.6	1.4	1.3	0.9

Fig. 7 Regional Comparison of Unlevered Equity Risk: Relative to the Morgan Stanley All-Country World Index (ACWI), the levered-equity beta for leading China-based solar companies (2.8) has been higher than the levered-equity beta for leading U.S.-based PV manufacturers (1.7). By normalizing for the perceived investment risk due to leverage (unlevered betas), we estimate the perceived country risk premium for China-based PV manufacturers: Chinese $\beta_{E,\,UL}$ / U.S. $\beta_{E,\,UL}$ = 1.5 / 1.1 = 1.3. Leverage and sectoral risk factors being equal and relative to U.S.-based PV companies, global equity investors require a 100% equity-return premium to invest in China-based PV companies (Table 10).

To calculate the EMRP for U.S.- and China-based factories in our model, we calculated the unlevered equity beta for existing publicly-traded U.S. ($\beta_{E,\,UL\ U.S}$ = 1.1) and China-headquartered PV companies ($\beta_{E,\,UL\ China}$ = 1.5) by unlevering the observed equity betas (β) for PV companies in each region based on the observed performance of PV industry stocks against a global

§ Average monthly return (8.4%), *Morgan Stanley USA Standard (Large+Mid Cap)* Index, www.msci.com, last accessed: February 29, 2012.
** Yield on ten-year U.S. treasury (2.29%), source: finance.yahoo.com, last accessed: February 29, 2012.
†† The term "Red Chip" was coined by Hong Kong economist Alex Tang in 1992.

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stock index (Fig. 7).[22] We estimate the perceived global-investor premium (~30%) that is attributable to country-risk in China. The reliance by China-based PV firms on debt further suggests the existence of equity premium and the importance of debt in financing the growth to date of this strategic sector.[24,25] Our results are not significantly higher than the regional costs of equity for firms located in the U.S. and China, involved in diverse sectors, and measured using alternative methods.[26,27]

Based on the International Capital Asset Pricing Model (Table 10), we find the cost of equity capital for Chinese PV firms to be approximately double that of U.S. companies.

The estimated WACC for the Chinese firm is, thus, approximately 50% higher than that for the U.S. firm, resulting in higher margin requirements for the China-based PV firms. Without accommodating these return requirements, a company will reduce its value (*i.e.* destroy, rather than create, shareholder wealth), likely driving higher future equity costs, thus limiting growth or increasing the dependence on debt financing. This result is of particular importance to manufacturers of PV products, a sector that may have significant untapped potential if further innovations can be achieved and commercialized.

Shipping Costs

The cost to transport modules or other solar equipment from a production location to an overseas-customer site includes the costs incurred by both the exporting and importing companies (*i.e.*, manufacturer and customer). Often, a manufacturer will incur the cost of carriage, including all fees, up to and including the loading of the shipment onto a vessel—in International Commercial terms ("Incoterms"), this is known as freight on board (F.O.B.). The cost of transporting the shipment, unloading it (including all applicable import duties and fees), and carrying it from the port of entry to the customer location is then incurred by the customer. From our total cost of ownership perspective, it matters not which entity incurs these costs, only that all costs are included in our benchmarking analysis.

All costs are per forty-foot equivalent (F.E.U.), unless specified	**U.S. to China**	**China to U.S.**
Basic Ocean Freight (BAS)	$967	$1,860
Inland Haulage Import (IHI)	$385	$385
Bunker Adjustment Factor (BAF)	$380	$380
Handling Charge - Destination (DHC)	$390	$390
Equipment Management Fee (EMF)	$8	$8
Import Intermodal Fuel Surcharge (IFS)	$72	$72
Documentation Fee - Origin (ODF)	$31	$31
Handling Charge - Origin (OHC)	$137	$137
Port Additionals / Port Dues - Export (PAE)	$40	$40
Carrier Security Charge (SER)	$9	$9
Transport Document Issuance Fee (BLF)	$19	$19
Freight Collection Fee (CLF)	$50	$50
Customs Clearance (CUS)	$23	$23
Export Service Charge (EXP)	$8	$8
Lift On Lift Off (HDL)	$100	$100
Shipper-Owned/Leased Equipment Charge (SOC)	$(200)	$(200)
Total Container shipping costs	**$2,418**	**$3,311**

Table 1. PV Module Shipping Costs: Container shipping costs, including fees, but excluding insurance and working capital. Source: Maersk company website: www.maerskline.com (last accessed: 1 March 2011).

In addition to the container-shipping costs, insurance is required. While in most F.O.B. situations it is the customer, rather than the manufacturer, who bears the cost of insurance, for our regional benchmarking purposes, it only matters that all costs are included—the assumption being that the customer will include such costs in an effective (landed) price when comparing offshore and domestic suppliers.

Once the shipment has landed in port, handling fees and carriage (transport to customer site) costs will be incurred. For the purposes of this analysis, we assumed intermodal shipping from Los Angeles, California, to a major desert-southwest location: Phoenix, Arizona (356 miles).

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All costs are per forty-foot equivalent (F.E.U.), unless specified	U.S. to China	China to U.S.
Insurance \$1.0 per \$1000 estimated value (E.V.)	\$1,136	\$946
Entry bond \$6.5 per \$1000 E.V.	\$615	\$615
Merchandise processing fee 0.34% of E.V.	\$317	\$317
Container shipping costs \$380 bunker adjustment factor, plus all handling fees	\$2,418	\$3,311
Carriage to customer site 1.75/mile, 356 miles	\$623	\$623
Total shipping costs	\$5,109	\$5,813
Container size (W per container) 504 modules, 14.9% module efficiency	145,686	
Total shipping costs per $W_{P\,DC}$	**\$0.035**	**\$0.04**

Table 2. PV Module Shipping and Logistics Costs: Total shipping costs, including container-shipping costs, insurance, bond, and handling fees, but excluding the cost of capital (typical steaming time from China to west coast U.S. = 14 days). Sources: Maersk company website: www.maerskline.com (last accessed: 1 March 2011) and Suntech. [28]

Based on the reported packing density for standard wafer-based silicon modules (504 modules per container) and an assumed efficiency of 14.9% (289 $W_{P\,DC}$ per 1.94 m^2 module), we estimate that each container holds approximately 145 $kW_{P\,DC}$, resulting in a landed-cost of \$0.04/$W_{P\,DC}$.[29] Today, manufacturers based in China tend to have a significant scale-based advantage, which may be leveraged to negotiate lower module-material prices, resulting in a China-based module manufacturing cost advantage of ~\$0.12/$W_{P\,DC}$.

For the advanced case (22.4% module efficiency, 435 $W_{P\,DC}$), assuming the same module size and packing efficiency, the total cost is ~\$0.03/$W_{P\,DC}$, compared to a China-based cost advantage of less than \$0.01/$W_{P\,DC}$, in the long-run. This implies that, as module manufacturing costs fall and large-scale production outside of China levels today's apparent regional cost advantage, the industry will likely prefer regional module-manufacturing locations to serve local end markets.

Sources of Material Discounts

The price of input materials for solar wafers, cells, and modules varies based on technology choices, customer (manufacturer) size, and sourcing strategies. The price of materials may also vary by region due to regional input costs, such as energy for glass production.

	Wafers	Cells	Modules
10% scale-based discount	All non-polysilicon feedstock consumables	All, excluding wafers and silver paste	All, excluding cells
5% regional material discount	All non-polysilicon feedstock consumables	Process chemicals, specialty gases, aluminum paste	Backsheet film
15% regional material discount		Screen-printing screens	Encapsulant film, tabbing ribbons, solder, front glass, frame, j-box & wires

Table 3.China-Based Material Price (Supply-Chain) Advantages: Summary of supply-chain advantages: China-based factories enjoy a 10% purchasing leverage deriving from increased customer scale (2,000 MW/year vs. 500 MW/year); additional regional price discounts ranging from 5% to 15% are shown for specific materials used in PV manufacture.

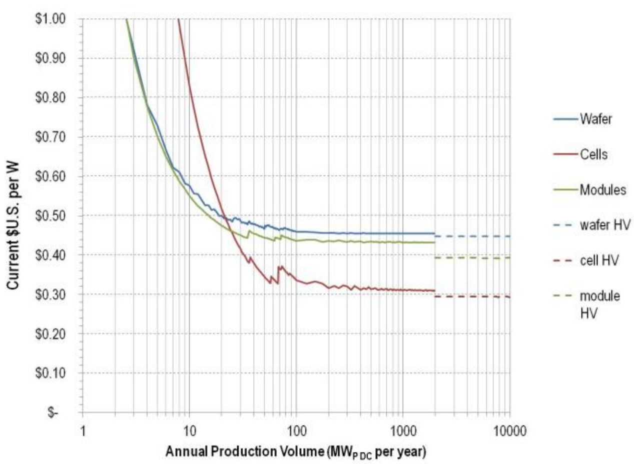

Fig. 8. Solar PV Manufacturing Price: Sensitivity to Production Scale: U.S. c-Si PV component MSP as a function of annual production volume (scale), including 10% scale-based materials discount above 2 GW annual production volume.[2]

Trends in PV Manufacturing Productivity

As the PV industry has matured, the scale of process equipment (tools) and factories has risen. For example, since 2005, the average available size of tube-diffusion furnaces used in the manufacture of crystalline silicon PV cells has increased from about 700 to 1,100 wafers per hour (Fig. 9), while the number of tool operators has remained constant—increasing productivity by nearly 60%. At the same time, the conversion efficiency of PV cells has risen by approximately 15%-20%, and module efficiencies have risen from 12.5% to 14.5%.

Because of these trends, labor costs per watt of PV device output have decreased by more than 80% since 2005. Through these advancements in productivity, the PV industry has reduced greatly the incentive to locate factories in so-called low-cost-labor regions.

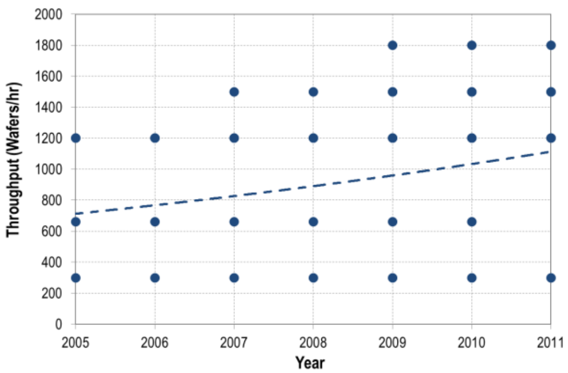

Fig. 9 Throughput Enhancements: Tube Diffusion Furnaces: Commercially available tube-diffusion furnaces: throughput ratings (dots) and average trend (line).[30-36]

		Unskilled (USD/hour)	Skilled (USD/hour)	First line supervisors (USD/year)	Benefits on wages and salary
China [37,38]	*Urban units*	*$3.21*	*$4.67*	*$16,355*	*54%*
	Urban units and TVEs	**$1.62**	**$2.36**	**$8,267**	**32%**
	Town, Village Enterprises (TVEs)	*$1.19*	*$1.74*	*$6,090*	*8%*
U.S. [39,40]	*High*	*$18.01*	*$24.61*	*$90,855*	*55.4%*
	Average	**$12.05**	**$17.56**	**$61,426**	**55.4%**
	Low	*$8.57*	*$11.88*	*$34,267*	*55.4%*

Table 4. Regional PV Manufacturing Wage and Compensation Rates: 2012 national average manufacturing-wage and compensation rates estimated using 2010 and 2008 data inflated at 3% and 10%, for manufacturing employees in the U.S. and China, respectively.

	MSCI ACWI	Zhong Hua	China Standard (Large + Mid Cap)	China A Standard (Large + Mid Cap)	China Red Chip	China P Chip
Start date	Jan 29, 1988	June 30, 2008	Jan 29, 1993	Jan 31, 2001	Dec 31, 2004	Dec 31, 2004
Average annualized return	6.2%	2.6%	4.1%	10.2%	18.0%	5.1%
Variance	0.002					
Covariance		0.005	0.002	0.002	0.003	0.004
$\text{Beta}_{\text{Levered}}$		1.1	1.2	0.6	1.0	0.4

- Note: $\text{Beta}_{\text{Levered}}$ = Covariance of stock or index divided by the variance of the MSCI ACWI over the same period.

Table 5. Comparison of the Volatility of China Stock Indices to Global Equity Market: Estimates for the country risk adjustment (β_{China}) of China, as depicted by the historic returns of five separate Chinese-stock indices relative to the global-equity market, represented here by the Morgan Stanley Country Index All-Country World Index (MSCI ACWI). Source: www.msci.com (last accessed: March 1, 2012).

	MSCI ACWI	Suntech Power Holdings Co. Ltd. NYSE: STP	Trina Solar Limited NYSE: TSL	Yingli Green Energy Holding Co. Ltd. NYSE: YGE
Start date	June 30, 2008	June 30, 2008	June 30, 2008	June 30, 2008
Average annualized return	-1.3%	-25.3%	2.2%	-6.7%
Variance	0.005			
Covariance		0.013	0.014	0.012
$\text{Beta}_{\text{Levered}}$		2.8	3.0	2.7
$\text{Beta}_{\text{Unlevered}}$		1.4	1.6	1.4

Table 6. Comparison of the Volatility of China-Based Solar PV Companies to Global Equity Market: By unlevering the observed equity beta for each of the leading Chinese PV firms, one can isolate that portion of the equity-return premium attributed by global-

equity investors to country and market (PV) risk factors (average $Beta_{Unlevered} = 1.5$). By comparing PV companies located in multiple locations, such as China-based domestics and U.S.-based but global firms (Tables 5 and 6, Fig. 7), one can normalize for market risk, thus isolating the country-risk adjustment. Source: finance.yahoo.com/ (last accessed: March 1, 2012).

	MSCI ACWI	**SunPower NasdaqGS: SPWR**	**First Solar NasdaqGS: FSLR**
Start date	June 30, 2008	June 30, 2008	June 30, 2008
Average annualized return	-1.3%	-41.2%	-36.7%
Variance	0.005		
Covariance		0.006	0.009
$Beta_{Levered}$		1.9	1.4
$Beta_{Unlevered}$		1.3	0.9

Table 7. Comparison of the Volatility of U.S.-Based Solar PV Companies to Global Equity Market: By unlevering the observed equity beta for each of the leading U.S. PV firms, one can isolate the premium attributed by global-equity investors for country and market (PV) risk factors (average $Beta_{Unlevered} = 1.1$). By dividing the average unlevered equity beta of China-based domestic PV firms (Fig. 7) by the average unlevered equity beta for U.S. based global PV firms (Table 6, Fig. 7), one can isolate the country-risk premium assigned by global equity investors to China ($\beta_{Unlevered,\ China} = \beta_{Unlevered,\ China\ PV\ companies} \div \beta_{Unlevered,\ U.S.\ PV\ companies} = 1.5 \div 1.1 = 1.3$). Source: finance.yahoo.com/ (last accessed: March 1, 2012).

	MSCI ACWI	**S&P 500 NYSEArca: SPY**
Start date	Dec 31, 1987	Dec 31, 1987
Average annualized return	6.2%	3.7%
Variance	0.002	
Covariance		0.002
$Beta_{Levered}$		0.86

Table 8. Comparison of the Volatility of Major U.S. Stock Index to Global Equity Market: To determine the country-risk adjustment for the U.S. ($\beta_{U.S.}$), the performance of the S&P 500 is compared to the global stock market (MSCI ACWI). Source: finance.yahoo.com/ (last accessed: March 1, 2012).

($U.S. millions)	**2007**	**2008**	**2009**	**2010**	**2011**
Suntech Power Holdings Co. Ltd. *NYSE: STP*	10.8	1.7	5.1	8.2	(32.4)
Trina Solar Limited *NYSE: TSL*	11.7	7.3	11.4	16.8	(1.8)
Yingli Green Energy Holding Co. Ltd. *NYSE: YGE*	9.6	8.7	(7.3)	11.1	(21.9)
SunPower *NasdaqGS: SPWR*	1.2	(8.7)	2.3	7.5	(26.0)
First Solar *NasdaqGS: FSLR*	31.4	28.0	31.0	25.9	1.4

Table 9. Reported Net Income for Major U.S. and China based PV Manufacturers: According to the as-reported net incomes for many of the leading publicly traded c-Si PV manufacturers, 2011 PV module prices do not appear sustainable. Source: respective annual reports (20-F filings with U.S. SEC). finance.yahoo.com/ (last accessed: March 1, 2012).

	U.S. (today)	U.S. (long-term)	China (long-term)	China (today)
Leverage ratio[24,25]	41%	23%	26%	53%
Cost of debt[11]	4.6%	4.6%	4.9%	3.1%
Expected rate of inflation[9]	2.9%	2.9%	3.2%	3.2%
Real cost of debt	1.7%	1.7%	1.7%	-0.1%
EMRP global	7.1%	7.1%	9.5%	9.5%
Beta target country	0.9	0.9	1.3	1.3
EMRP target country	6.1%	6.1%	9.5%	9.5%
Unlevered PV equity beta	1.1	0.7	0.7	1.1
Levered corp. equity beta	1.7	0.8	0.8	2.1
Global risk-free rate	2.3%	2.3%	2.3%	2.3%
Cost of equity	12.3%	7.1%	10.2%	22.5%
WACC	**8.6%**	**6.2%**	**8.5%**	**12.0%**

Table 10. Weighted average cost of capital (WACC) calculations: U.S. and China observed-today (2012) and expected long-term values.

		U.S. (500 MW per year facility)			China (2,000 MW per year facility)		
		High	Expected	Low	High	Expected	Low
Unskilled Direct Wages	USD/hr	$18.01	$12.05	$8.57	$3.21	$3.21	$1.19
Skilled Direct Wages	USD/hr	$24.61	$17.56	$11.88	$4.67	$4.67	$1.74
Indirect Salary	USD/year	$90,855	$61,426	$34,267	$16,355	$16,355	$6,090
Tier 1 Material Discounts		0.0%	0.0%	5.0%	10.0%	15.0%	15.0%
Tier 2 Material Discounts		0.0%	0.0%	15.0%	10.0%	25.0%	25.0%
Equipment Price Discounts		-10.0%	0.0%	10.0%	10.0%	50.0%	90.0%
Electricity Price	USD/kWh	$0.13	$0.07	$0.04	$0.08	$0.02	$0.02

Table 11. Manufacturing Cost Model (Standard Technology): Uncertainty Analysis Assumptions: Standard technology (1H 2012) scenario: key assumptions used in uncertainty analysis.

		U.S. (2,000 MW per year facility)			China (2,000 MW per year facility)		
		High	Expected	Low	High	Expected	Low
Unskilled Direct Wages	USD/hr	$18.01	$12.05	$8.57	$3.21	$3.21	$1.19
Skilled Direct Wages	USD/hr	$24.61	$17.56	$11.88	$4.67	$4.67	$1.74
Indirect Salary	USD/year	$90,855	$61,426	$34,267	$16,355	$16,355	$6,090
Tier 1 Material Discounts		0.0%	10.0%	15.0%	10.0%	15.0%	15.0%
Tier 2 Material Discounts		0.0%	10.0%	25.0%	10.0%	25.0%	25.0%
Equipment Price Discounts		10.0%	50.0%	90.0%	10.0%	50.0%	90.0%
Electricity Price	USD/kWh	$0.13	$0.07	$0.04	$0.08	$0.08	$0.02

Table 12. Manufacturing Cost Model (Advanced Technology): Uncertainty Analysis Assumptions: Advanced technology scenario: key assumptions used in uncertainty analysis.

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