Chapter 4

First Solar Case – Competitive Pressure, Growth and Rate of Return

Using Case Study of First Solar to Review Solar Power Economics

The case study of First Solar Corporation discussed in this chapter involves valuation issues for companies in fast growth industries where product differentiation is difficult. The case is also used to review dramatic trends in the economics of solar power and the challenges in earning economic rents any segment of the business. Mechanics of measuring the cost of solar power production are also documented.

The basis for discussion of the case discussion is a write-up by Stanford University titled "First Solar, Inc. in 2010" (the case has been updated in 2013, discussing tariffs).[1] A similar case was published in 2009 by HBS that discussed NanoSolar, a company that manufactured panels using the same technology as First Solar called thin film and was experiencing the same type of challenges as First Solar.[2] Both of these case write-ups provide a general background on solar power as well as discussion of corporate strategy and finance. Data from the cases is updated to 2018. Additional sources of information for the discussion of First Solar in this chapter include a series of ValueLine reports for the company that illustrate how investment analysts sometimes compute equity value as well as First Solar annual reports to shareholders.

In general, HBS cases and Stanford cases are very complementary of First Solar and management (cases are often written by managers of companies who are former Harvard or Stanford students). Some of the laudatory phrases written by the authors of the First Solar case write-up include: "…accomplishments had indeed been impressive", "the remarkable achievements of the exceptional people…", "the industry leader…", "…prowess in manufacturing", and, "financial performance had been

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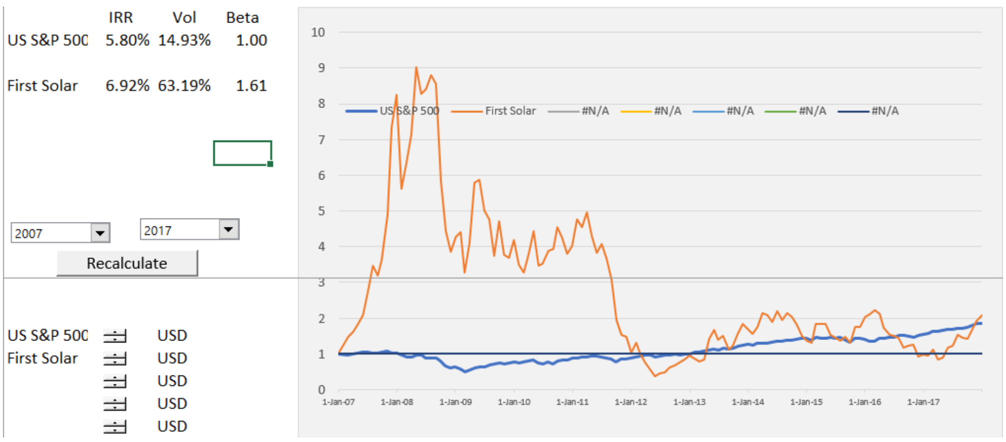
[1] Hallmon, Morgan, Siegel, Robert and Burgelman, Robert "*First Solar, Inc. In 2010*", 10/01/10, by the Board of Trustees of the Leland Stanford Junior University. An update of the case was published in 2013 discussing tariffs on Chinese Manufacturers.

[2] Steenburgh, Thomas J. and Wagonfeld, Alison, "Nanosolar, Inc." October 15, 2009, Copyright © 2009 President and Fellows of Harvard College.

impressive...” The First Solar case as well as the HBS NanoSolar cases even include resumes of key management in an appendix.

The First Solar case takes place after the financial crisis of 2008, when growth prospects for the sale of panels dimmed in Europe. In response, First Solar believed it could “leverage” its manufacturing skills to become vertically integrated, meaning that First Solar would develop, construct, own and operate projects over their lifetime as well as continuing to manufacture panels. As an integrated solar company, it believed it could generate value to its shareholders by competing in markets without government subsidies. But the new strategy of First Solar did not result in an increased stock price. Prices of solar equipment plummeted, and First Solar’s stock price declined by a further 80%. Nanosolar, the company that is subject of the similar HBS write-up, experienced a worse fate than First Solar. Nanosolar ceased its operations and lost just about all of the money invested by its shareholders. By February of 2013 Nanosolar had laid-off 75% of its work force and it was auctioning off its equipment in August of 2013.

The stock price graph below for First Solar shows how, after the Lehman collapse in 2008, First Solar’s stock price had fell more than half. But this decline was after a meteoric rise providing investors who bought the stock in 2006 with 12 times their investment.[3] Relative to the stock price at the IPO date, the 2010 price at the time of the case write-up was still almost six times as high by the end of 2010.

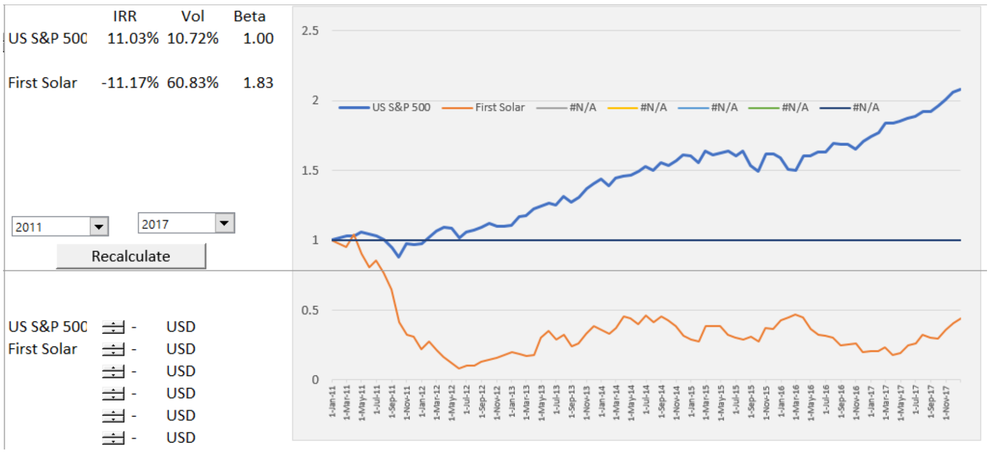


The general idea of First Solar’s “innovative” management strategy was that the company could maintain its shareholder value by entering the development, construction and operation segments of the solar industry through taking advantage of its manufacturing abilities. In this way the return on investment that had been obtained in manufacturing could be maintained. The implicit assumption was that returns above the cost of capital – economic rents – could be earned in other segments of the business when they could not be

[3] This graph as well as other stock price graphs are made from files that can be found on the website www.edbodmer.com. A video explanation of how to download stock price data is also included.

earned in the manufacturing segment. Just like in any business, to earn returns above the cost of capital there must be competitive advantage from marketing, cost structure efficiency, product design or other things that limit competition. The underlying question in the First Solar case is why would returns fall off in the manufacturing segment without having similar declines from competitive pressure in other parts of the industry.

To implement its development and EPC strategy, First Solar acquired a series of development companies that were in various segments of the "downstream" business (i.e. parts of the industry that involve developing, constructing, operating and financing after manufacturing of panels). The company paid substantial premiums relative to book value for these companies (resulting in a lot of goodwill on its balance sheet). For these acquisitions to be profitable for First Solar, the business would not only need to earn a reasonable return, but they would have to earn a return above the cost of capital after paying a premium for the business.



The case is also used to consider valuation and strategic challenges in the solar power industry. When a business such as manufacturing of solar panels or development of a solar farm does not have much differentiation, it is difficult to realise prices that produce a lot of economic rent to shareholders. Many will suggest that this is not so. Manufacturers will assert that they have unique technology; developers will say that they found a unique site; investors will suggest that they have found efficient financing; and managers will tell you they can operate the panels in a superior manner. But when all these items are put out to bid, and as the business becomes global, earning high returns in any part of the business is a delusion. Studying the solar business demonstrates these ideas.

A Very Brief History of the Solar Industry Since 2004

To provide background for First Solar's strategy of entering other segments of the industry, the Stanford case includes a history of the solar power industry that describes the production process; subsidy and pricing schemes (feed-in tariffs, PPA agreements, capital subsidies and renewable energy credits); grid parity analysis; and, balance of system costs that include inverters, wiring, labour, racks and engineering. The cost structure and pricing of solar power is brought up to date (early 2018) in this article, culminating in pricing bids for below 2 U.S. cents per kWh in Mexico (ENEL) and Saudi Arabia (EDF) and 4.5 cents per kWh in Zambia (NEON from France).

Let's now step back. One of essential elements in the recent history of solar power was the policy of Germany and other European countries that subsidized solar power with feed-in tariffs (prices paid to solar power producers). This high feed-in tariff was designed to spur the industry to attain larger scale. Larger factories, familiarity of banks with the technology, understanding of solar resources, and knowledge of how to maintain equipment would reduce unit cost (the cost per kWh). Government intervention was deemed necessary by European governments as un-subsidized markets would not enable companies to have the patience to increase production capacity.

The feed-in tariff implemented by Germany and other countries was nice and simple. It was a flat price available to anybody who could produce solar power and send it to the grid (no transmission constraints to worry about). It did not change with inflation or the level of merchant wholesale electricity prices. This fixed price had an important effect of reducing the cost of capital for the projects by allowing predictable cash flow and project finance. There was no need to negotiate complex purchased power agreements ("PPA") and the tariff was not limited to selected corporations that spent a lot of money on developing bids.

In 2004, the price of power on the German wholesale market was about 30 Euro per MWH (this is 3 Euro cents – 30/1000 to get kWh and multiplied by 100 to express in cents). The German feed in tariff for ground mounted large installations was 45.7 Euro cents or 457 Euro per MWH. That is a big subsidy. Trends in the feed-in tariff and wholesale prices are demonstrated in the two graphs below. During the time subsidies were in place (e.g. 2004-2008) there was a saying that coal power plants were driven by mining coal, nuclear power was driven by extracting uranium, natural gas plants were driven by piping natural gas and solar plants were driven by government subsidies. With prices below 2 US cents per kWh, such sayings have stopped and even the most hardened old utility executives are acknowledging solar power economics.

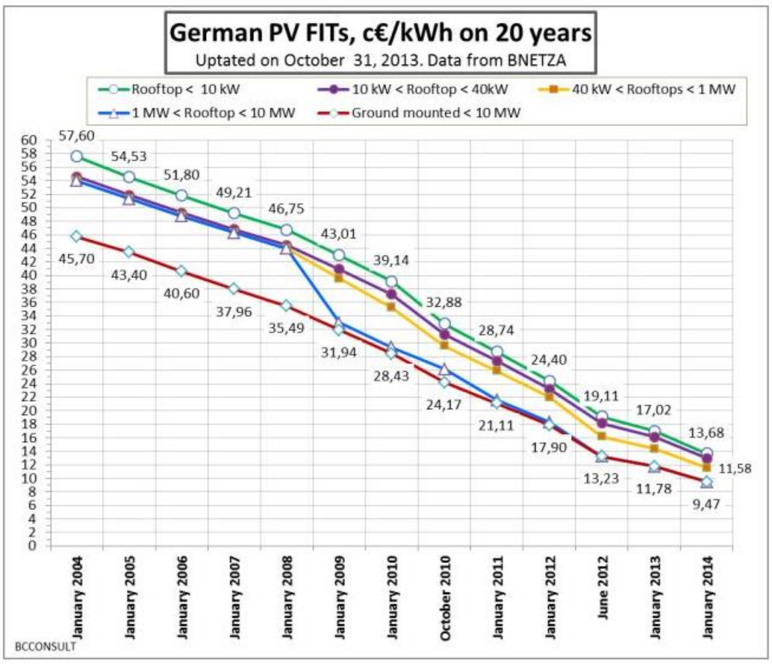
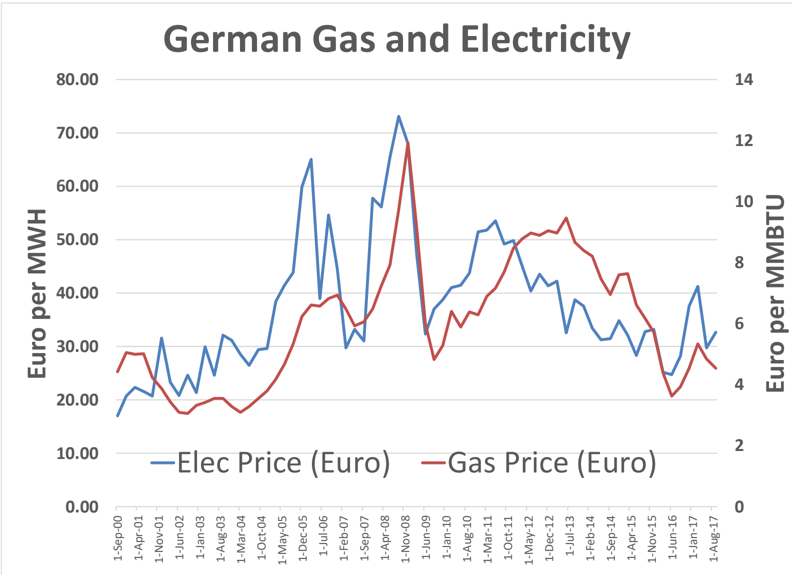


Figure 3: German PV FITs history from 2004 and up to January 2014



From the standpoint of developing solar power, the subsidy structure in Germany was marvellous. The policy did arguably lead to a revolution in the solar industry and the feed-in tariffs can be used as an example of effective government intervention in a market. As shown in above graph, the feed-in tariff was dramatically reduced to the point where it is almost competitive with conventional technologies.

The case study describes how First Solar predicted falling solar power prices. This prediction did materialize. Recent solar power projects have been able to produce electricity for less than 2-3 U.S. cents per kWh which is competitive with other technologies and far less than residential electricity prices in most areas of the world.[4] The lower prices in solar power contracts have been driven by dramatic reductions in module and inverter costs; reductions in O&M costs; lower financing costs and development of solar power in regions of the world with elevated levels of irradiation.

Levelised Cost of Electricity and Four Elements You Need to Compute Solar LOCE

The Stanford case write-up of First Solar included a general discussion of the levelized cost of electricity (LCOE) in the context of evaluating whether solar power is competitive with other technologies. This statistic which is expressed as an amount per kWh or MWH has been used for a long time in the electricity industry and has become popular lately in evaluating renewable energy. Discussion of the dramatic transactions that were below 2 U.S. cents per kWh generally refers to this LCOE number. The LCOE is also analogous to the flat feed-in tariffs per MWH discussed in the context of the German government policy.

LCOE is supposed to put together the total cost of producing power by a certain technology over the its lifetime. Costs include amounts for recovering capital costs and the total costs are spread over the amount of electricity that is produced from a technology. You could compare the LCOE of a nuclear plant with a solar plant with your electricity bill with the cost of production from a diesel unit. None of this would be correct because of comparing intermittent capacity with baseload capacity; the ability to dispatch some projects and not others; and the value of distribution and transmission. Nevertheless, use of the LCOE statistic as a benchmark has become common. Working through the LCOE for solar power demonstrates the difficulty in earning high returns in any segment of the solar power business and the importance of attaining low cost financing.

The high cost (LCOE) of solar power associated with German feed-in tariffs was driven by: (1) the fact that the sunlight does not produce the same amount of energy over the course of the year and over the course of a day – especially in most of Germany. This means that the capital cost of equipment must be spread over a limited kWh units produced; (2) the relatively high capital cost (cost per kW) of an installed system including panels, wiring, inverter costs, racks and labour (in 2010 the cost per kW of maximum power output was more than an expensive coal plant even though it may produce small amounts of power relative to the maximum capacity); (3) the cost of capital (solar power is probably just about the most capital intensive endeavour on earth with virtually all of its costs represented by up-front capital); and (4) operation and maintenance costs that should be modest and require cleaning of

[4] A project in Dubai agreed to a PPA contract with a price of 6 cents per kWh in 2015. The next year, a contract was signed for 3 cents. Later, a contract for 2.34 cents per kwh was singed in Abu Dhabi. See the website for DWEA.

panels at night time as well as insurance, inverter replacement and administrative costs.

The LCOE may seem like a complicated statistic, but if it is the nominal LCOE, it is just the weighted average nominal price of electricity over the lifetime of a facility. The word levelization in LCOE can be taken literally – i.e. levelling out or averaging. To compute LCOE, you just levelize or average prices that move up and down over time. To be more precise, the levelization is a weighted average rather than a simple average that accounts for discounting and degradation. By computing LCOE as the NPV of revenues divided by the NPV of generation, the amount of power production as well as the time value of money are both implicitly considered in the calculation. As the levelized cost measures average cost over the life of a project adjusted for a given discount rate and is better to expressed in real terms as the current production cost of electricity.[5]

Nominal LCOE =

NPV(Nominal Discount Rate, Revenue)/NPV(Nominal Discount rate, Generation)

Real LCOE =

NPV(Nominal Discount Rate, Revenue)/NPV(Real Discount rate, Generation)

The LCOE can be computed from components of the cost of a solar facility using the following basic formulas. In this example an assumption is made that the cost will ultimately be expressed in terms of €/MWH:

Inputs:

- Start with Plant Cost including Panel Cost and Balance of System Cost expressed in €/kW or € million/MW or €/W;
- Evaluate the cost of O&M per kW-year;
- Compute Carrying Charge Rate (% of total up-front cost recovered in a year);
- Estimate Capacity Factor or Yield (% of time running at maximum output), or the yield in hours at maximum capacity (kWh/kWp);

Component Calculations:

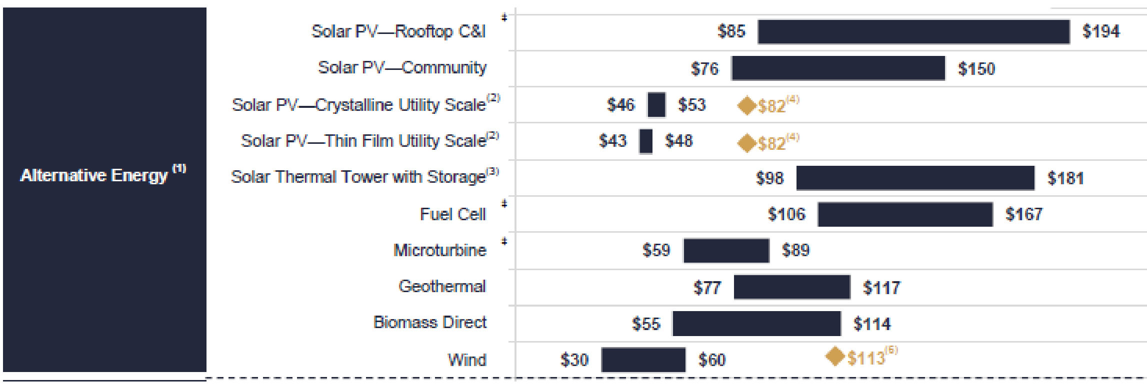
- Annual Capital Cost Recovery (€/kW-year) = Plant Cost x Carrying Charge
- Annual Capital Fixed Cost (€/kW-year) = Capital Recovery (€/kW-year) + O&M Cost Charge (€/kW-year)

Final LCOE Calculation:

[5] The real levelised cost of electricity can be computed as the net present value of revenues divided by the net present value of the kWh generation computed at the real discount rate.

- LCOE (€/MW-hour) = Annual Charge (€/kW-year) /Generation Hours
- LCOE (€/MW-hour) = Annual Charge (€/kW-year) / (8760 * Capacity Factor)
- LCOE (€/MW-hour) = Annual Charge (€/kW-year) / Yield

Many organisations publish the LCOE of solar power and other technologies. The International Energy Agency (IEA) documents the cost of actual projects in different countries every five years (for example, you can find the cost/kW, the operation and maintenance cost and the capacity factor for the gigantic hydro plant in China). The IEA's sister agency, the International Renewable Energy Agency (IRENA) produces detailed reports of expected costs. The U.S. Energy Information Agency (EIA) regularly publishes statistics on capital costs, O&M costs and capacity factors (but the solar power costs are typically very high). A study that is often quoted is a study regularly published by the investment bank Lazard Freres. The excerpt shown below demonstrates that Lazard estimates LCOE for ground-mounted solar of between $4.3 cents per kWh and $5.3 cents per kWh without storage. The diamonds show that with storage, the cost increases to $8.2 cents per kWh.



While the LCOE calculations include capital costs, operating cost, capacity factor and the capital recovery factor, the statistic can be difficult to use in economic analysis.[6] Comparisons made using the LCOE are not adjusted for dispatchability nor the ability to quickly adjust to changes in demand. The LCOE does not typically include the costs of storage that may be necessary for off-grid systems. Inputs to the LCOE – capacity cost, O&M cost, capacity factor and carrying charge -- provide a framework to consider the potential to earn high returns in any segment of the business. Discussion of the different inputs, in particular the carrying charge rate, allow independent calculation of the LCOE.

[6] People associated with conventional power such as professors who are paid by utility companies will often point out these problems.

Capital Cost per Watt of Solar Modules

The main cost of a solar power facility is the up-front capital cost. To evaluate cost, the capital cost is measured relative to its capacity to produce electricity at any instant. Typical cost measurement is in terms of the cost per watt or the cost per kW. Capacity measurement, expressed as kWp or MWp allows a benchmark for measuring capacity factor or yield as well as cost. But measuring capacity in kWp or MWp of a solar panel or module[7] is not like measuring the capacity of a dispatchable thermal plant or the maximum speed of your Maserati. If there is no sunlight, there is no capacity. You cannot turn the knob or a solar project or put your foot on the gas pedal to run at maximum output. The electric capacity from solar power is measured with a flash test at the solar manufacturing factory by assuming that 1,000 watts of solar irradiation per meter squared occurs under what is termed standard testing conditions (STC). The test also is made at 25 degrees Celsius as shown in the excerpt below.

YGE-U 72 CELL SERIES

Powered by YINGLI

ELECTRICAL PERFORMANCE

Electrical parameters at Standard Test Conditions (STC)							
Module type			YL310P-35b	YL305P-35b	YL300P-35b	YL295P-35b	YL290P-35b
Power output	P_{max}	W	310	305	300	295	290
Power output tolerances	ΔP_{max}	%	-0 / +3				
Module efficiency	η_m	%	15.9	15.6	15.4	15.1	14.9
Voltage at P_{max}	V_{mpp}	V	36.3	36.1	35.8	35.6	35.3
Current at P_{max}	I_{mpp}	A	8.53	8.45	8.37	8.29	8.22
Open-circuit voltage	V_{oc}	V	45.6	45.4	45.2	45.0	44.8
Short-circuit current	I_{sc}	A	8.99	8.93	8.86	8.79	8.73

STC: 1000W/m² irradiance, 25°C cell temperature, AM 1.5g spectrum according to EN 60904-3
Average relative efficiency reduction of 3.3% at 200W/m² according to EN 60904-1

Electrical parameters at Nominal Operating Cell Temperature (NOCT)

GENERAL CHARACTERISTICS

Dimensions (L / W / H)	77.56in (1970mm) / 38.98in (990mm) / 1.97in (50mm)
Weight	57.3lbs (26kg)

PACKAGING SPECIFICATIONS

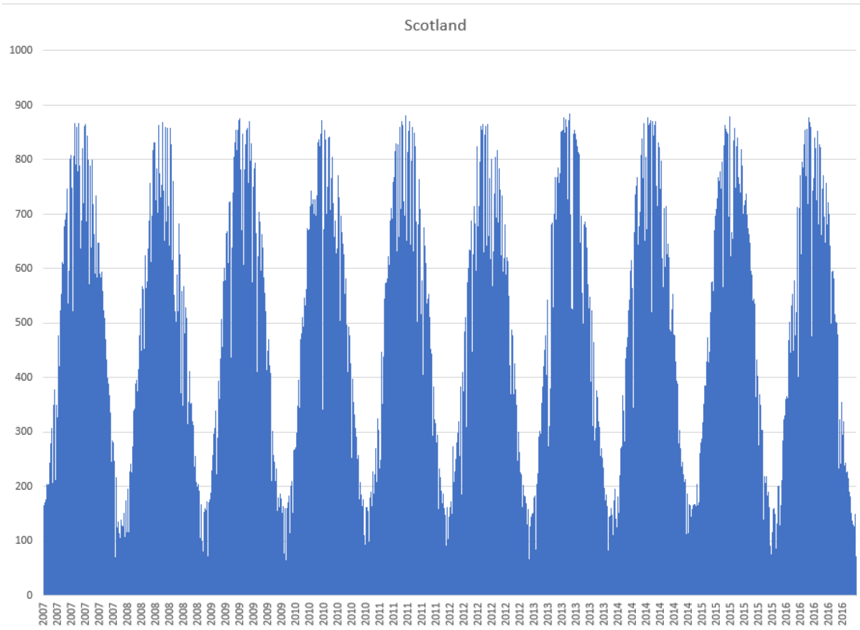
Number of modules per pallet	21
Number of pallets per 40' container	24
Packaging box dimensions (L / W / H)	78in (2000mm) / 45in (1145mm) / 46in (1170mm)
Box weight	1307lbs (593kg)

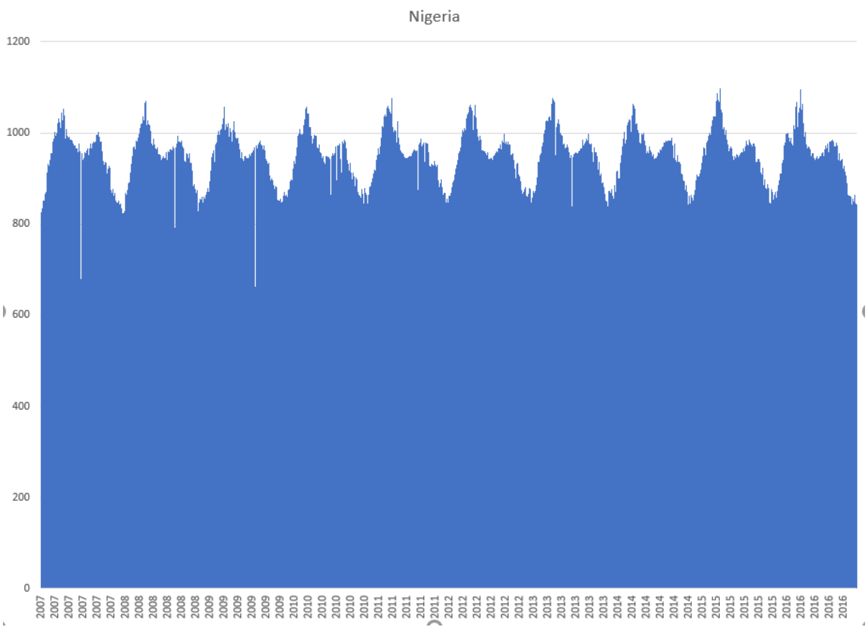
Units: inch (mm)

The issue of measuring and capacity is demonstrated by data on the amount of sunlight or irradiation that hits a horizontal plane. The maximum amount of irradiation expressed in terms of kWh per meter squared on a flat plane demonstrates that the maximum amount of capacity depends on the location of the facility and that the STC is an arbitrary measure. This is illustrated in the two graphs below that show the irradiation per meter squared for Scotland and Nigeria on an hourly basis (taken from a wonderful EU website). Because Scotland is far north of the equator, 1,000 watts per meter squared does not occur on a flat plane even on the sunniest day of the year (the maximum irradiation on a day around the summer solstice that is not cloudy

[7] A module represents perhaps 23 cells. This is the typical unit of measurement rather than a single panel. An array may have 50 modules.

depends on the latitude of the location).[8] On the other hand, in Nigeria the 1,000 benchmark for measuring the cost of capacity is regularly exceeded.



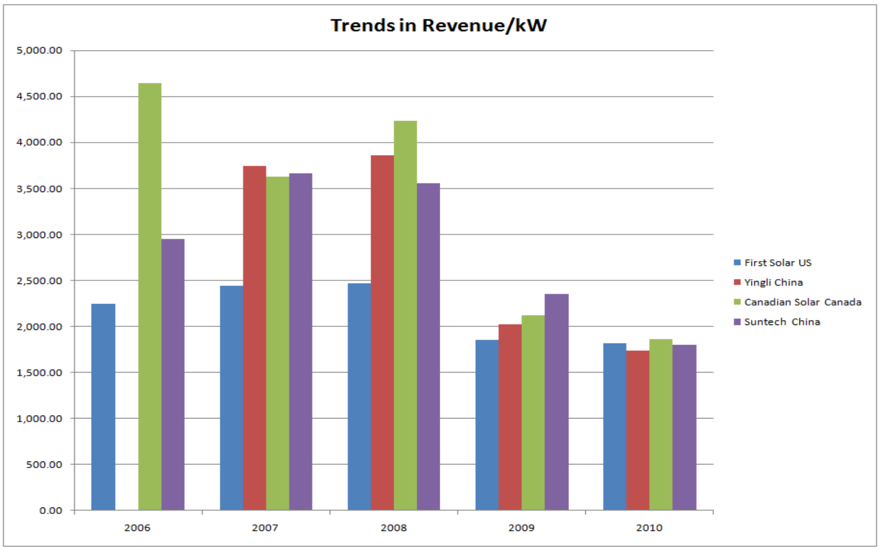


With a little background on benchmark capacity, the cost of solar modules per kWp or MWp can be evaluated. In the ten-year period between 2008 and 2018, the cost per kW of capacity for modules declined by a factor of 10 from more than USD 4,000 per kW to less than 300 per kW. Before 2010 a rough measure of the pricing of solar panels could be obtained from the

[8] In Chicago, for example, the maximum level of irriadiation of 1,000 from 1991 to 2010 was. Chicago has a longitude of 41.87, -87.63. Paris has a latitude 48.85. Key West is 24.55.

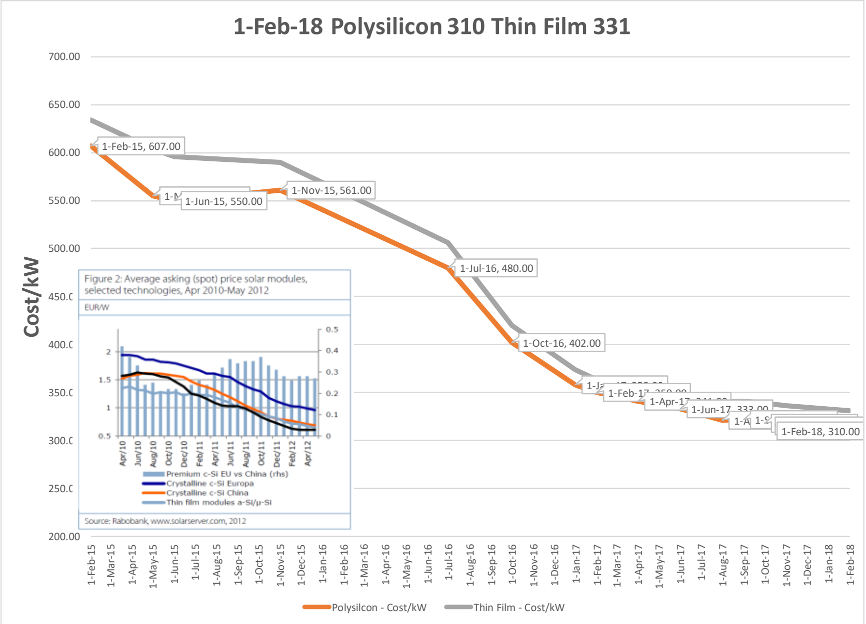
financial reports of manufacturing companies through dividing reported revenues received by selling panels by the amount of production in MW. When measured on this basis, the approximate price charged per kW from 2006 to 2010 for different companies is shown below. The graph demonstrates that the price charged by First Solar in 2010 was not much different than the price charged by other firms. The first graph below demonstrates that the cost of modules was about $3,500 per kW in 2008. This price dramatically declined in the subsequent years. By 2018, the price had fallen to about $300 per kW.[9] Further, by 2010, the there was no clear price advantage for the thin film process relative to polysilicon technology.

By 2018 the cost fell to $310 per kW as shown in the second graph.



The Stanford case write-up notes that at the time of the discussion in 2010, solar panels were becoming more and more of a commodity. The commodity nature of panels is demonstrated by a website called PV Insight which publishes the cost per kW of thin-film and polysilicon panels on a daily basis. Data from this website shown below lists the cost of panels (as well as the price of silicon and the cost of inverters).

[9] Figure 6.2 is derived from annual reports; current costs can be derived from the website www.pvinsight.com



Total Cost Including Balance of System per Watt

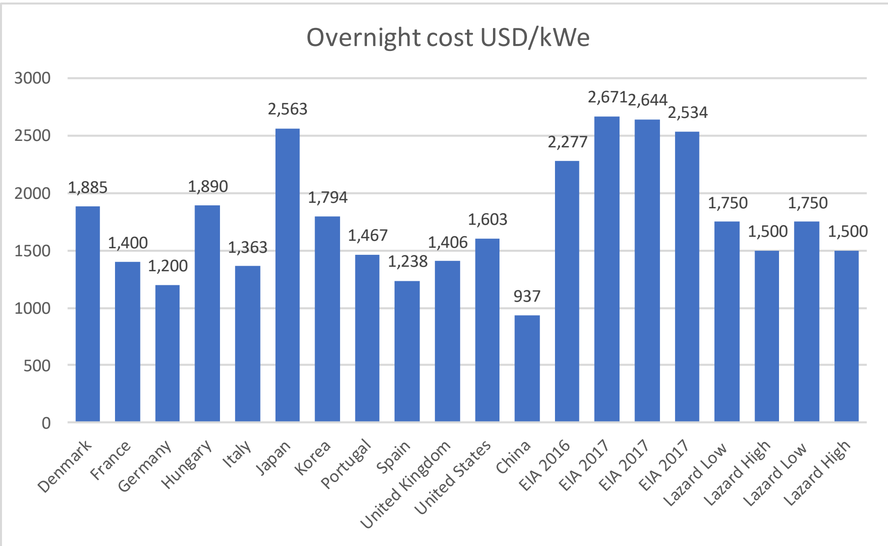
A strategy of First Solar was presumably that it could earn a better margin as an EPC contractor and realise profit from sources other than panel manufacturing. First Solar would install solar arrays and manage the process of wiring facility and connecting it to the grid. For these services the company would earn a profit margin. Earning a profit on the EPC contracts is like other economic activities. The profits depend on the ability to differentiate products and the amount of risk taken in the endeavour. The process of constructing solar farms is far less complex than the construction of just about any other electricity technology. In theory the margin an EPC contractor earns is function of the risk taken.

There are a lot of things to add to the cost of modules in installing solar power. This includes inverters, installation, labour, development costs and other items. An aggressive solar cost estimate is shown in the table below. Even though the cost of panels is $305 per kW, the total cost is $745 per kW.[10] Part of process of evaluating a financial model, the you should first compute the cost per kW.

[10] First Solar, Inc. in 2010, page 2.

Capital Expenditures and EPC Contract		
EPC Cost per kW		
Module Cost and Transport	USD/kW	305.37
Inverter Cost	USD/kW	79.90
Tracker Cost	USD/kW	
Sub-total	USD/kW	385.26
Balance of System	USD/kW	184.39
Installation and Other	USD/kW	138.93
Total EPC Cost	USD/kW	708.58
Land Cost	USD/kW	0.00
Development Cost	%	5%
Development Cost	USD/kW	37.29
Development Fees	USD/kW	0.00
Total Cost Including Development	USD/kW	745.87

While such a low cost may be possible, there is a wide range in observed cost per kW. The graph below demonstrates this range when taking data from the different LCOE sources including the IEA, the EIA and Lazard.



An example of high cost is shown in the table below. In this example, a 1.4 MW plant in the U.S. had a much higher cost per kW of $1,781. As the panel cost is presumably similar to any other project, the balance of system costs are much higher. When more and more projects have a cost more like $1,000 per kW, making margins from a relatively simple construction process.

Operating Period		31-Mar-43	FALSE	FALSE	FALSE
General Operating Assumptions					
Model Start	Date	30-Nov-16			
COD	Date	31-Mar-18			
Operating Life	Years	25.00			
Decomissioning	Date	31-Mar-43			
Construction Months/Period	Months	1			
Start of Quarterly	Date	31-Dec-17			
Operation Monts/Period	Months	3			
Months of Construction	Months	13			
Construction and Capacity					
Capacity	kW	1,466			
Cost/kW	USD/kW	1,781			
		Total		30-Nov-16	31-Dec-16
Construction Expenditures	USD	2,611,268		-	-
S-Curve	%			0.00%	0.00%
Revenues and Operating Expenses					
Generation	kWh/yr	1,748,865	437,216		
Yield	kWh/kWp	1,193			
Capacity Factor	%	13.62%			
Degradation	%	0.00%			

O&M Cost per kW-year

Operation as well as capital costs must be included in the LCOE calculation which is supposed to capture all costs of producing power. While operation cost may have been relatively minor in the context of total LCOE in the past because of the high capital cost of solar power, it can be tricky in terms of acquiring and interpreting data. From the perspective of the First Solar Case Study an issue is whether the company could make money through operating projects in an efficient manner. It is also becoming more important as capital costs decline. In developing solar projects, the provision of O&M can be performed by a company that does not own the project.

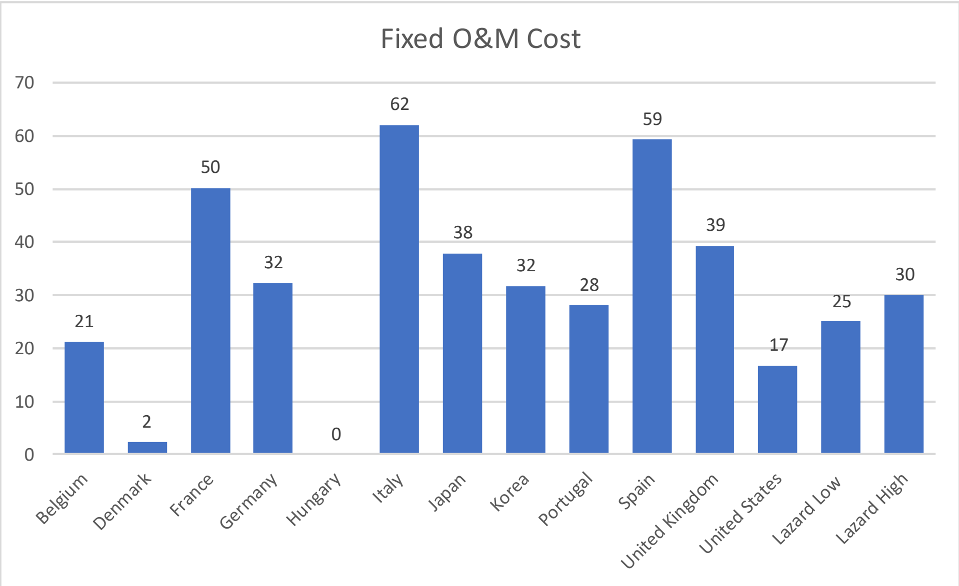
The first question in addressing operation costs is what should be included in the O&M costs. Specifically, should the cost number per kW-year include land rent, insurance, royalties, consultancy, administrative and so forth. The answer is that the LCOE should include all the operating costs because the LCOE is a number that represents the total cost of electricity. For solar power just about all of these costs are fixed, as it is difficult to think of costs that vary according to whether there is more or less sunlight on a particular day.

Finding objective data on the O&M costs is much more difficult than the capital cost analysis and when you do find quoted cost data, the costs are rarely segregated. Lazard estimates the O&M cost per kW-year to range between U.S. 9 per kW-year an U.S. 12 per kW-year as shown in the table below.

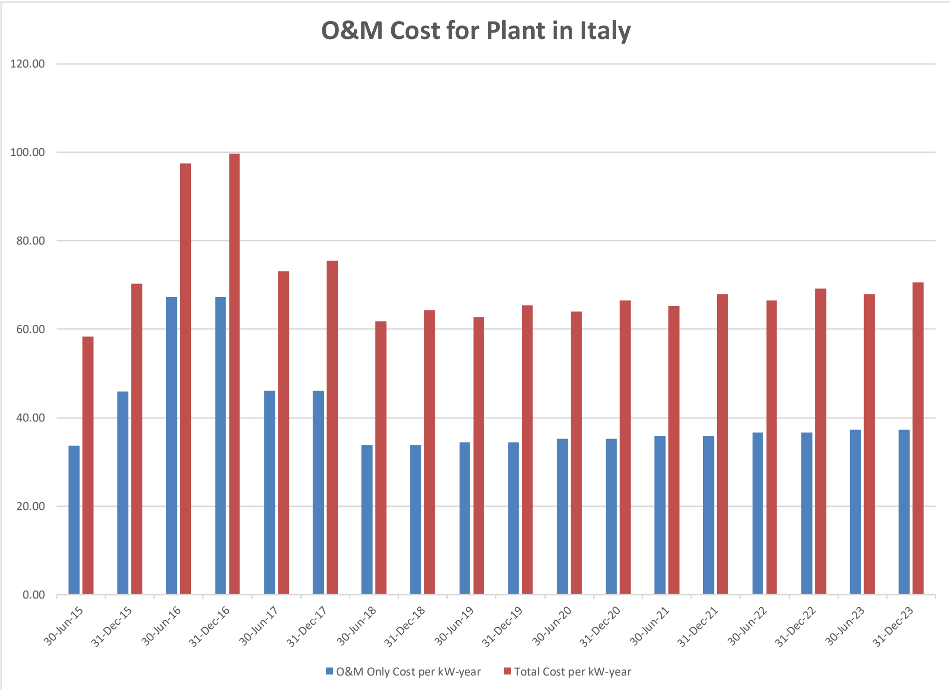
Levelized Cost of Energy—Key Assumptions

		Solar PV				
	Units	Rooftop—Residential	Rooftop—C&I	Community	Utility Scale—Crystalline [3]	Utility Scale—Thin Film [3]
Net Facility Output	MW	0.005 - 0.002	1	1.5	30	30
EPC Cost	$/kW	$3,125 - $3,560	$2,000 - $3,750	$1,938 - $3,125	$1,375 - $1,100	$1,375 - $1,100
Capital Cost During Construction	$/kW	—	—	—	—	—
Other Owner's Costs	$/kW	included	included	included	included	included
Total Capital Cost [1]	$/kW	$3,125 - $3,560	$2,000 - $3,750	$1,938 - $3,125	$1,375 - $1,100	$1,375 - $1,100
Fixed O&M	$/kW-yr	$20.00 - $25.00	$15.00 - $20.00	$12.00 - $16.00	$12.00 - $9.00	$12.00 - $9.00
Variable O&M	$/MWh	—	—	—	—	—
Heat Rate	Btu/kWh	—	—	—	—	—
Capacity Factor	%	18% - 13%	25% - 20%	25% - 20%	30% - 21%	32% - 23%
Fuel Price	$/MMBtu	0	0	0	0	0
Construction Time	Months	3	3	4 - 6	9	9
Facility Life	Years	20	25	30	30	30
CO_2 Emissions	lb/MMBtu	—	—	—	—	—
Levelized Cost of Energy [2]	$/MWh	$187 - $319	$85 - $194	$76 - $150	$46 - $53	$43 - $48

The chart below illustrates the variation in cost per kW-year for different LCOE studies. The country by country variation is derived from the IEA report. The cost per kW-year in USD varies from almost zero to more than $50 per kW-year for France, Italy and Spain. If the cost is $50 and the capacity factor is 15%, the cost per year is USD 38/MWH. In past feed-in tariff regimes, these costs could have allowed high profits for O&M providers. With the costs moving down to USD 9/kW-year these profits are no longer available.



The graph below shows the cost per kW (in €/kW-year) for a single solar project in Italy that was developed during the time of high Feed-in tariffs. The costs of pure O&M are displayed along with the total costs that include insurance, administrative costs and other costs are displayed. The pure O&M costs are somewhat less than 40 €/kW-year, dramatically less than the current costs. The total costs are more than €/kW-year, consistent with the IEA data.



When presenting financial models, the LCOE for O&M can be computed in an equivalent manner as the rates. The levelized cost of O&M is computed as the present value of O&M costs divided by the present value of capacity or energy. There surely are economies of scale in O&M, meaning that the cost can be even less for large projects.

Yield (kWh/kWp) and Capacity Factor

The third factor that drives the LCOE of solar power is the capacity factor. For an airplane, a factor or a thermal plant, capacity factor is the average amount produced divided by the maximum production. For a solar project, the maximum capacity is defined as the amount of production at STC, which is not necessarily the maximum amount of power that can be produced. Instead of speaking in terms of capacity factor, yield is often used. The capacity factor is expressed as a percent and the yield is measured in equivalent hours as the kWh/kWp. If you have the yield and the capacity expressed in kWp, you can compute the kWh. The yield can be expressed it terms of equivalent hours operating at maximum capacity. The yield divided by the hours in a year is the capacity factor. The capacity factor can also be expressed as average production (kWh/8760) divided by the maximum production (kWp).

The solar resource establishes the amount of energy you can generate over the course of the year relative to the maximum capacity of the solar panels dictated by the STC. The amount of energy produced from the sunlight in a given area depends on the efficiency of the panels which defines the capacity that is expressed as the kilowatts at peak conditions or kWp. The energy production in kWh must account for actual sunlight and must be subsequently adjusted for the tilt of the panels, degradation[11], dust, snow and sand on the panels, as well as temperature and other losses related to inverters that convert power under direct current which is the basis for kWp into electricity hat can be transmitted to the electricity grid that is measured with alternating current (AC).

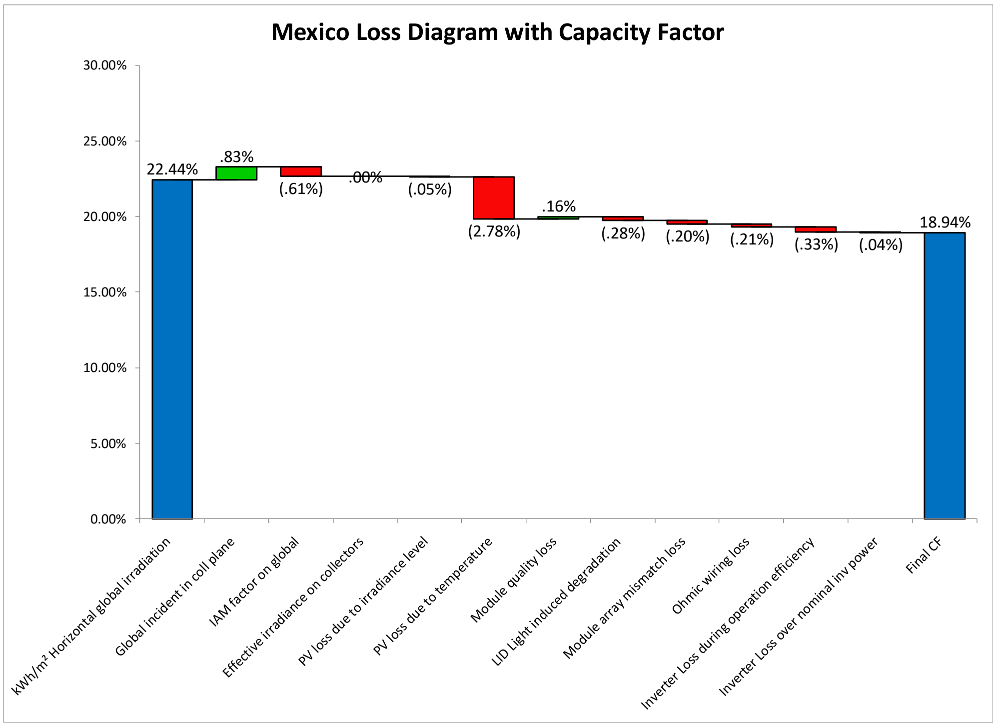
The capacity factor of a solar project is thus driven by two things. First is the amount of sunlight that hits the panel (the collectors) that has nothing at all to do with the type of panels, the wiring or anything other than the tilting of the solar project. The second is the performance ratio (PR) which is largely driven by temperature. The PR is defined as amount of the losses from temperature and other factors relative to the theoretical amount of power that could be produced without the losses. While different panels have different reactions to temperature, if you know the irradiation and the temperature (on the panels) you can probably get a good estimate of the capacity factor. Further, unlike the situation for wind, you can get pretty good solar data from public sources on the internet. This is another factor that makes differentiation of solar power more difficult than other technologies.

When you are working through reports from PVSYSYT or another service, there are a lot of seemingly confusing outputs. You can simplify all of this by understanding that STC is computed from 1,000 watts per meter squared and that the performance ratio (PR) is the capacity factor on the plane relative to the final capacity measured at alternating current.

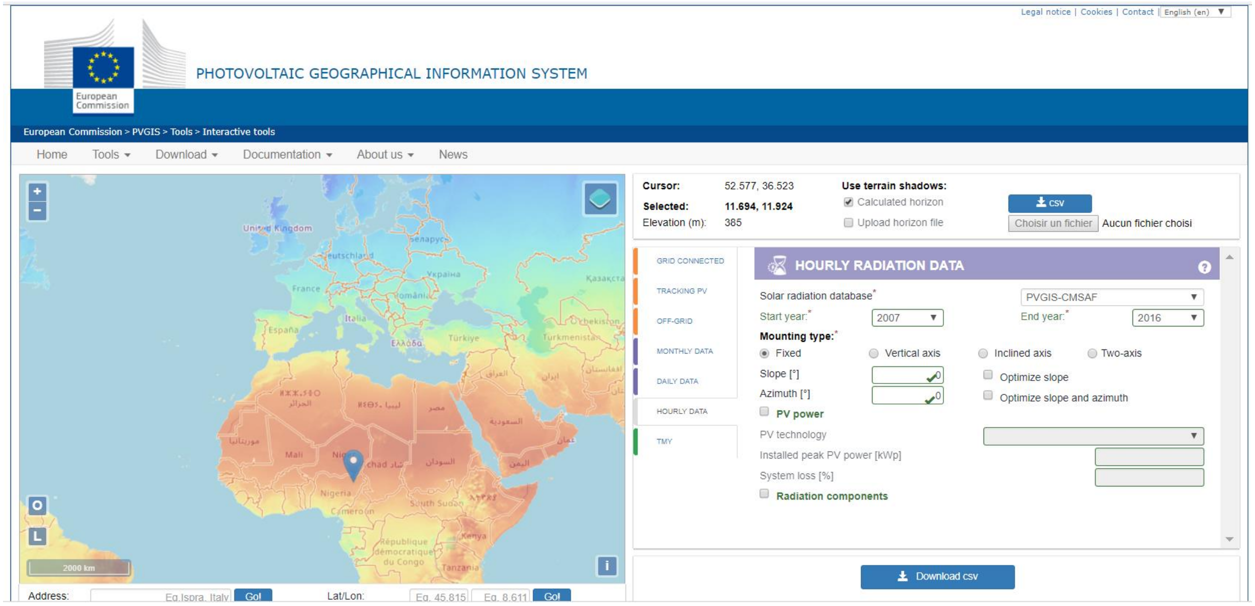
PR = Capacity Factor at Collectors/Final Capacity Factor

PR = (1-Temperature Loss %) * (1-Wiring Losses %) * (1-Soiling Loss %)

[11] Typical assumptions are that the output decreases by 1.5% in the first year and .4% for each year thereafter.



A website funded by the EU with multiple years of historic irradiation data and options for computing irradiation with different tracking strategies is shown below. This website provides very good irradiation data from satellite data.



Irradiation data and performance ratio data from alternative sources is demonstrated in the table below. The data on irradiation do vary and there is some variation in the performance ratio. As more and more studies are evaluated relative to actual results, this variation will be reduced. As with the other factors, presuming that a superior economic profit can be earned through making better estimates of solar resource is doubtful.

Point of Access Capacity Factor	Point of Access Irriadiation Capacity Factor	Electricity Production Capacity Factor	Performance Ratio
EU Data	22.90%	17.12%	74.78%
PVWatts	22.49%	16.69%	74.24%
PVSYST	23.28%	18.94%	81.36%
Helioscope	20.92%	16.37%	78.25%
Percent Difference (High/Low)	11.30%	15.72%	3.98%

Carrying Charge Rate

The final factor that drives the solar LCOE is the carrying charge rate that includes the cost of capital. This item is the most difficult to explain as it cannot be measured from a website with simple formulas. As solar is an extremely capital intensive the cost of that capital or the carrying charge is also a very important driver of cost. The carrying charge can be reconciled to project finance analysis.

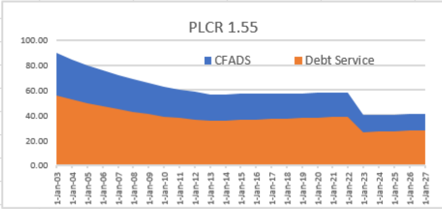
If the cost of capital were zero, there was no tax, no inflation, no degradation and no decommissioning, then the carrying charge would be one divided by the lifetime of the project. Say the project had a lifetime of 30 years and a cost of 1,000. Then the amount of money needed to recover the capital cost per year would be 33.33. The carrying charge would be 33.3/1000 or 3.3%. If the carrying charge of 3.33% would be multiplied by the capital cost of 1,000 then amount of money needed to recover the investment would be established. Hopefully this simple idea gives an idea of what the carrying charge is.

If cost of capital is included and there is no differentiation between the debt and equity cost of capital and the tax rate and inflation rate are zero, the carrying charge rate is the annuity value using the cost of capital and the rate (in excel you can use the PMT function). If the cost of capital is 3%, then the annuity value (from the PMT function) is 51.02 and the carrying charge is 5.1%. This gives a flat or level carrying charge which is precisely the notion behind levelized cost.

A problem with this levelization business is if there is inflation. With inflation, the cost is level in nominal terms, but the nominal values buy less of your Ferrari's in the future. The amount that should be levelized is an amount in real or un-inflated terms. To do this, all you have to do is to use the real cost of capital rather than the nominal cost of capital. Other adjustments for taxes, depreciation, construction timing, degradation and decommissioning should also be made. In the end you can derive a detailed carrying charge as illustrated in the table below.

Summary	Carrying Charge	5.65%	IRR	2.76%	WACC	2.76%	Equity IRR	6.00%	Equit

Assumptions						
Timing Assumptions					Life	26
Start Date	Date	1-Jan-01			Construction	16.00
Months in Period for Construction Period	Months	1.00				
Months in Period for Operating Period	Months	12.00			Debt to Capital	70%
					Real Equity Return	3.92%
Inflation Rate					Real Interest Rate	-0.25%
Inflation Rate	% p.a.	2.00%				
Degradation Rate	% p.a.	0.50%				
Net Inflation Rate		1.49%				
Periodic Inflation Rate - Construction	% p.p.	0.12%				
Periodic Inflation Rate - Operation	% p.p.	1.49%				
Returns and Capital Structure						
Equity Return	% p.a.	6.00%				
Base Risk Free Rate	% p.a.	1.75%				
Credit Spread	% p.a.	1.00%				
Total Interest Rate	% p.a.	2.75%				
Debt Percent	%	70%		70		



With the resource and the performance ratio established, the economics and LCOE can be computed from the capital expenditures, operation and maintenance cost and carrying charges. Finally, the cost of capital must be input that depends on required IRR, interest rates, debt terms, inflation rates and taxes. Using public data and different cost of capital estimates, the range of production costs from solar power is shown in Figure 4.3 and Figure 4.4. As with other analytical tasks.

With the carrying charge, the cost per kW, the O&M cost, the capacity factor and the carrying charge, the LCOE can be computed. In the first case a high capacity factor of 22%, low cost capital cost of 800/kW and a low operating and maintenance cost is applied. In this case it is possible to arrive at a price near 2 cents per kWh as shown below.

	D	E	F
1			
2	**Inputs**		
3	Cost per kW	USD/kW	800.00
4	O&M Cost	USD/kW-yr	7.00
5	Capacity Factor	%	23.00%
6			
7	Carrying Charge Rate	%	4.53%
8			
9	**LCOE Calculation**		
10	Annual Carrying Charge	USD/kW-yr	36.25
11	Fixed O&M Cost	USD/kW-yr	7.00
12	Annual Fixed Cost	USD/kW-yr	43.25
13			
14	**Total LCOE**	**USD/MWH**	**21.47**
15			
16	**Carrying Charge Factors**		
17	Equity IRR	% p.a.	6.00%
18	Interest Rate	% p.a.	3.50%
19	Debt to Capital	%	85%
20	Inflation Rate	% p.a.	2.00%
21	Tax Life	Years	10
22			

Comprehensive Example | Calculation

In an alternate case where the capacity factor is still 23%, the credit spread is 5%, the equity IRR is 16%, the LCOE increases to USD 4.6 cents as shown below.

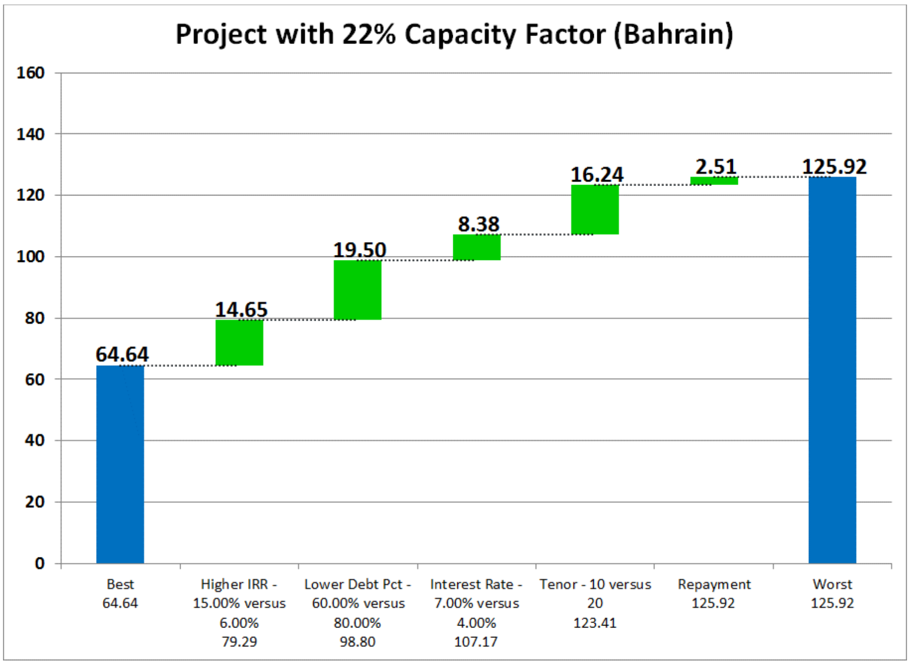
Inputs		
Cost per kW	USD/kW	800.00
O&M Cost	USD/kW-yr	7.00
Capacity Factor	%	23.00%
Carrying Charge Rate	%	10.68%
LCOE Calculation		
Annual Carrying Charge	USD/kW-yr	85.43
Fixed O&M Cost	USD/kW-yr	7.00
Annual Fixed Cost	USD/kW-yr	92.43
Total LCOE	**USD/MWH**	**45.88**
Carrying Charge Factors		
Equity IRR	% p.a.	16.00%
Interest Rate	% p.a.	7.50%
Debt to Capital	%	55%
Inflation Rate	% p.a.	2.00%
Tax Life	Years	10

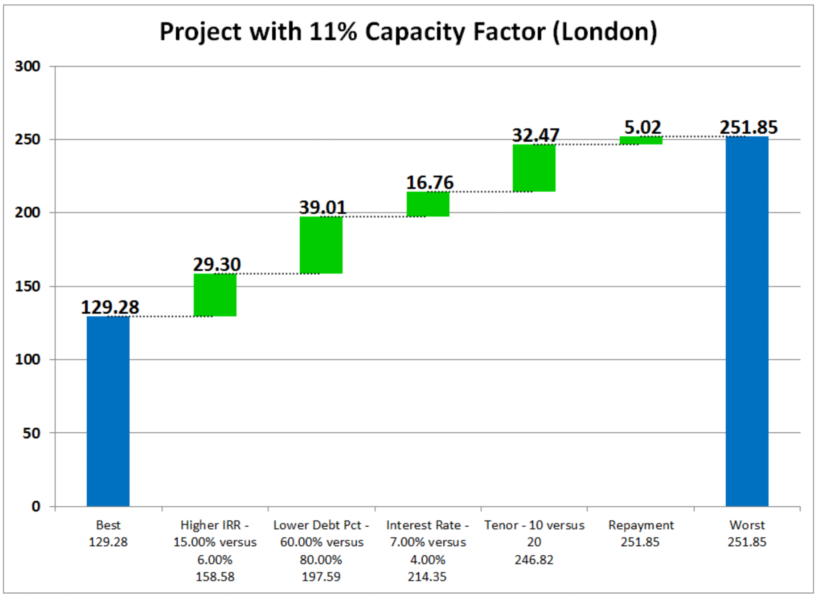
In a third scenario, the costs and financing are the same, but the capacity factor declines to 12.5% because of a different location. In this case the LCOE increases to 8.4 cents per kWh. These calculations demonstrate how dramatically different the cost of solar can be.

Inputs		
Cost per kW	USD/kW	800.00
O&M Cost	USD/kW-yr	7.00
Capacity Factor	%	12.50%
Carrying Charge Rate	%	10.68%
LCOE Calculation		
Annual Carrying Charge	USD/kW-yr	85.43
Fixed O&M Cost	USD/kW-yr	7.00
Annual Fixed Cost	USD/kW-yr	92.43
Total LCOE	**USD/MWH**	**84.41**
Carrying Charge Factors		
Equity IRR	% p.a.	16.00%
Interest Rate	% p.a.	7.50%
Debt to Capital	%	55%
Inflation Rate	% p.a.	2.00%
Tax Life	Years	10

The final charts in this section attempt to separate the various factors that drive the cost of solar power. With debt financing that is not as advantageous and an IRR of 15% is required, the levelised cost of electricity increases to $126 per MWH, almost double the real LCOE in the best-case financing. The

LCOE progression is on shown on the waterfall (sometimes called candle stick chart). With less aggressive financing and higher IRR's, the LCOE increases to 25.85 cents per kWh. This level of cost is cannot be supported without a subsidy in virtually any market in the world.





Differentiation of Thin-Film versus Polysilicon Technology

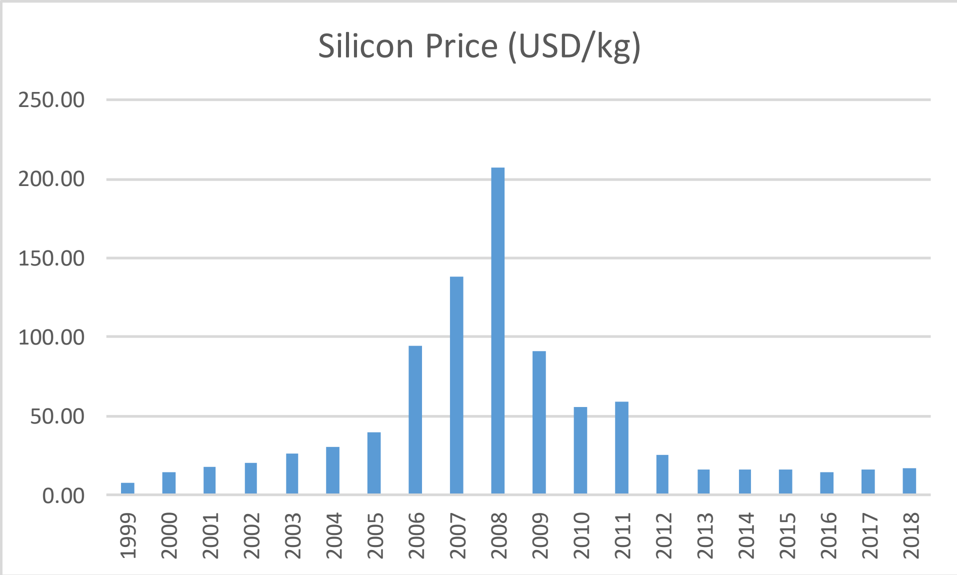
Once issues associated with the overall solar power industry are addressed, in the case study, the thin film technology of First Solar is contrasted to the more common polysilicon technology. The case writer asserted that the thin film production of solar panels applied by First Solar was superior to competing polysilicon technologies (primarily used by Chinese manufacturers).

This superior manufacturing technology, it is asserted, would enable the company to compete with conventional and other renewable technologies.

In non-technical parlance, polysilicon technologies are made by sawing silicon or refined sand (which is a semiconductor and can produce electricity using the photovoltaic process) into thin square panels. Thin film panels need substantially less raw material because the process involves coating – painting -- a thin layer of semiconductor material that has a photovoltaic property on top of a substrate (or base material) such as glass. But thin film panels have a lower efficiency in terms of producing sunlight irradiation (measured in kWh) into electricity energy (also measured in kWh). The lower efficiency means that more panels, sunlight and land were required to generate the same amount of electricity (although the cost per kW is expressed in terms of capacity and not in terms of area). This larger area can increase operation and maintenance, land payments, wiring and other costs.[12] Thin-film have better temperature coefficients and have somewhat better performance during cloudy periods. Polysilicon or c-Si panels had represented about 80% of the market in 2010 and the trend has continued.

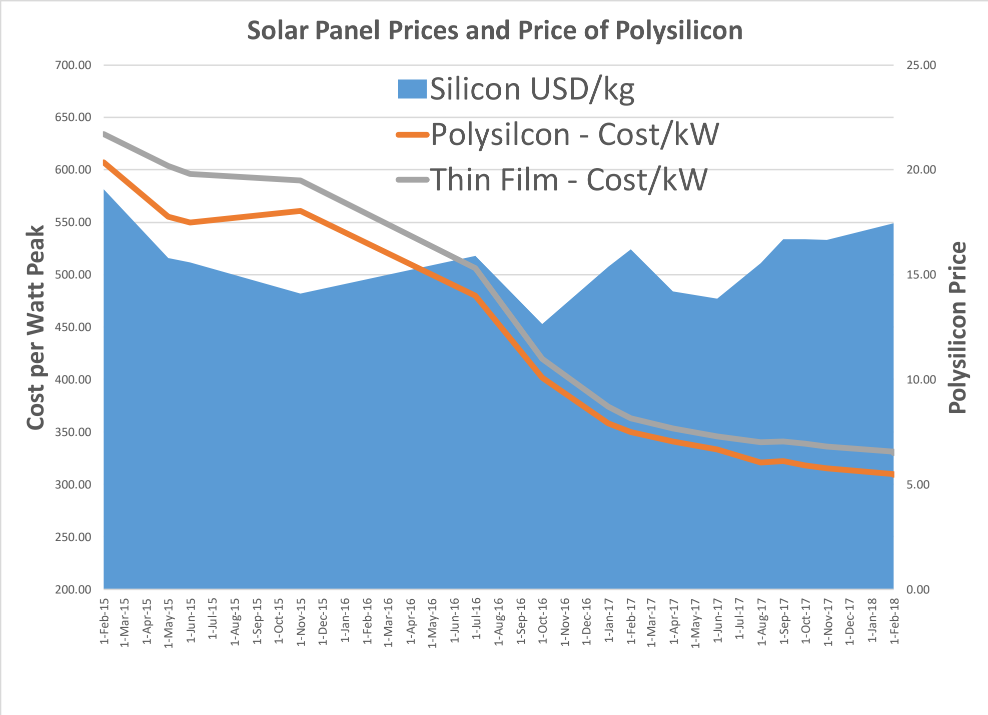
The Stanford case study suggested that the First Solar's thin film technology had an inherent cost advantage as compared to the polysilicon manufacturers: "[t]he simplicity of CdTe chemistry allowed its capital costs per watt of production to be substantially lower than that for competing technologies." This cost advantage is supposed to come from the high capital expenditures required to refine silicon and the high silicon prices that existed before 2008. But the cost advantage changed dramatically with a large decline in polysilicon prices that from 2009-2013. In 2008 the price of silicon began to fall dramatically from what arguably was a bubble before 2008 as shown in the graph below.

[12] According to the public database provided by RetScreen tool, the current efficiency of a First Solar panel ranges between 10% and 12.5% while the efficiency of a polysilicon panel made by Trina Solar panel ranges between 13.75% and 15%.



In analysing the manufacturing process and evaluating whether thin-film capacity has a competitive advantage, reasons for declines in the cost per kWp modules should be examined. At the time of the case in 2010, an increase in solar manufacturing production capacity had occurred in large part from entry by Chinese companies. A central question at the time was whether dramatic price reductions that occurred were due to surplus manufacturing capacity or other factors. These other things that could explain declines in the cost of panels included improvements in manufacturing productivity, declines in the cost of input materials and reductions in high profits enjoyed by companies. In considering surplus capacity economic impact, note that the panel production is not very capital intensive. The solar manufacturing process for polysilicon involves a big square building, purchase of raw silicon, equipment that cuts the silicon into pieces, quite a bit of energy and a lot of labour. If there is surplus capacity in the industry, the buildings can be converted to other uses and labour can be quickly dismissed.

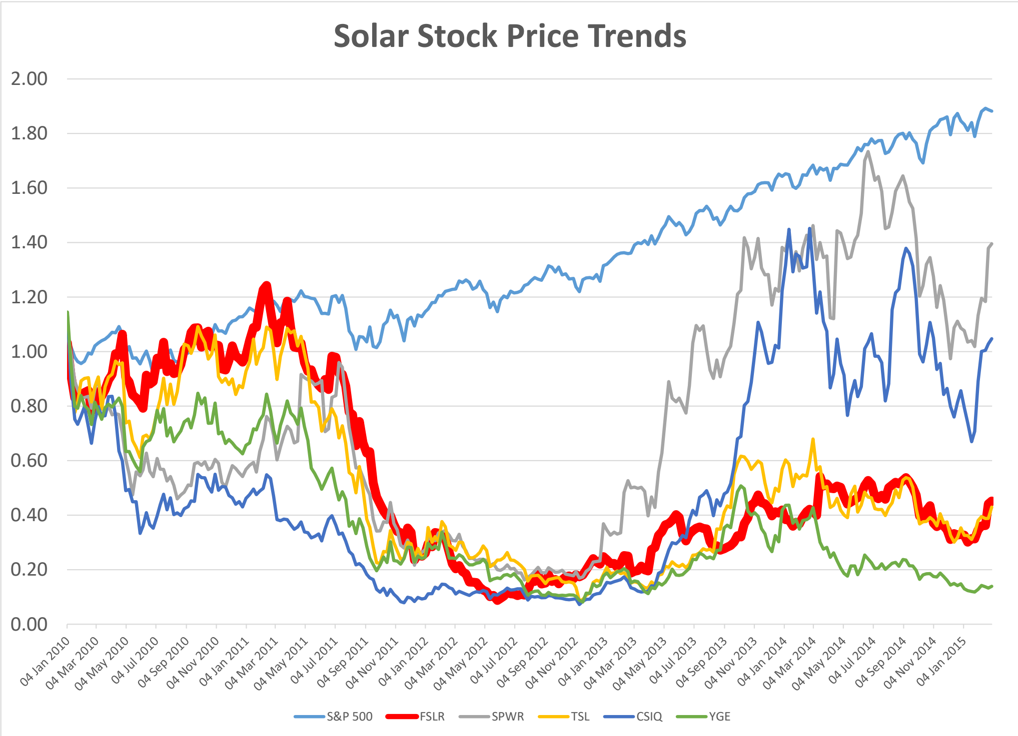
The relation between thin-film and polysilicon is demonstrated by a graph of the price of modules relative to the price of silicon since 2015. Note that the cost of polysilicon modules has continued to decline even though the price of silicon has stabalised or increased. There are some differences in thin-film and polysilicon other than efficiency.



Valuation of Solar Manufactures and Development Companies in the Solar Power Industry

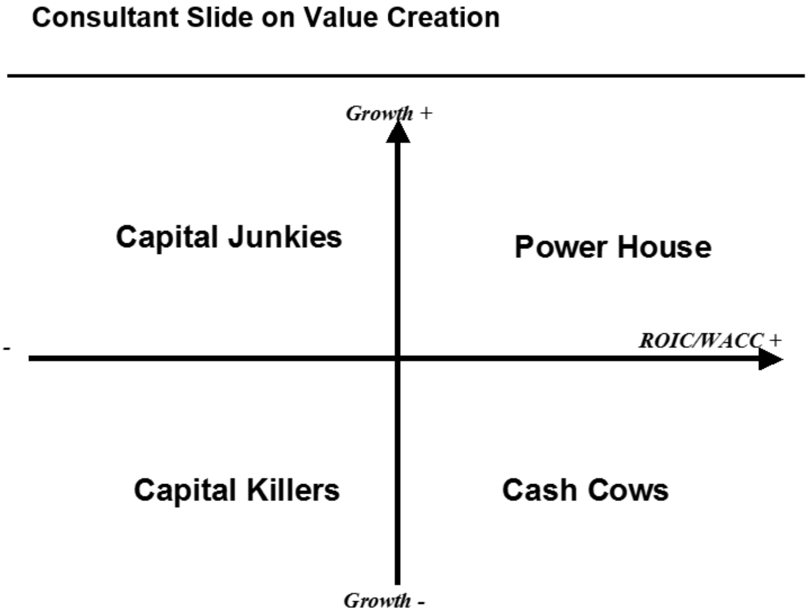
The case study of First Solar highlights dramatic changes in the cost of solar power as discussed in the preceding paragraphs. But the case study also raises general valuation issues associated with industries seem to be able to grow quickly and at the same time earn high returns. Sometimes these high growth/high return companies can realise high value over the long-term that justifies very high price to earnings and other multiples. But often the assumption that high growth accompanied by high returns can be established over the long-term is pure fantasy. This fantasy is often encouraged by Wall Street, Stanford Business School and management of corporations without thinking hard about worldwide competitive pressure. First Solar is an ideal case study to demonstrate the difficult valuation issues for a fast-growing and quickly changing industry.

One year after the case was written, the financial performance of First Solar dramatically deteriorated. The price of polysilicon did not rebound and there was no clear cost advantage for thin-film producers. The company did not produce at full capacity resulting in lower profits and a dramatic reduction in stock price. The First Solar's thin film manufacturing facility in Germany was closed and a new factory in Vietnam was cancelled. In 2011, the company took an impairment write-off for all of the goodwill that had been recorded for its acquisitions of downstream development companies. The failure of First Solar's stock price is illustrated below which compares the stock price of solar manufacturing companies to the overall market. The graph demonstrates that not only did First Solar's stock price fall along with the other companies, but that its performance was among the worst of in the industry (to be fair, the graph does not show the many other companies that ceased to survive).



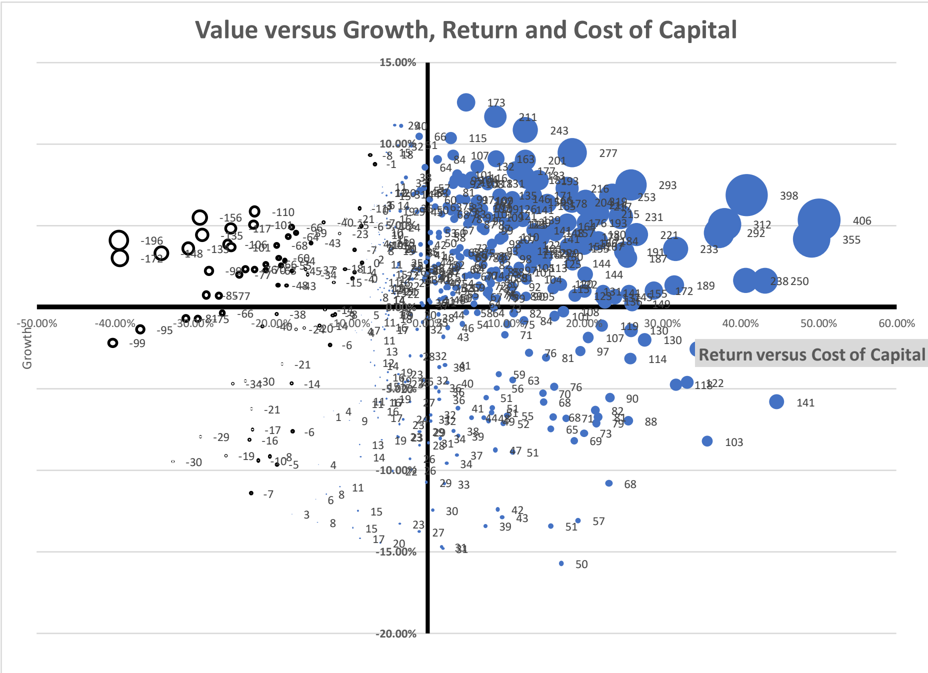
Analysing Returns and Growth

The fundamental objective of any business, whether a corporation or a project financed investment is to earn returns above the cost of capital. If returns on new investments are above the cost of capital, even more value can be gained for investors by growing the positive net present value operations. Earning returns above the cost of capital and growing rapidly put a company in the upper right-hand portion of the valuation matrix illustrated below. This square with high growth and high return is named the powerhouse square by consultants.



Before 2008 companies in the solar manufacturing industry seemed to be a very attractive investment and First Solar was surely one of the premier companies. The solar manufacturing companies were earning high returns and also growing at very quickly. The problem was that growth of the industry had been driven by subsidies and that Chinese entry could change the economics of the industry. Despite these structural issues, investors placed a lot of reliance on management guidance for the next year and the latest quarterly earnings per share results. The more important question for valuation was not the next quarter earnings but whether companies could sustain high returns and high growth over a long period. Financial analysts who made the explicit or implicit assumption that players in all segments of the solar industry ranging from making polysilicon to hiring workers to constructing arrays can earn large economic profits over a long period of time turned out to be wrong.

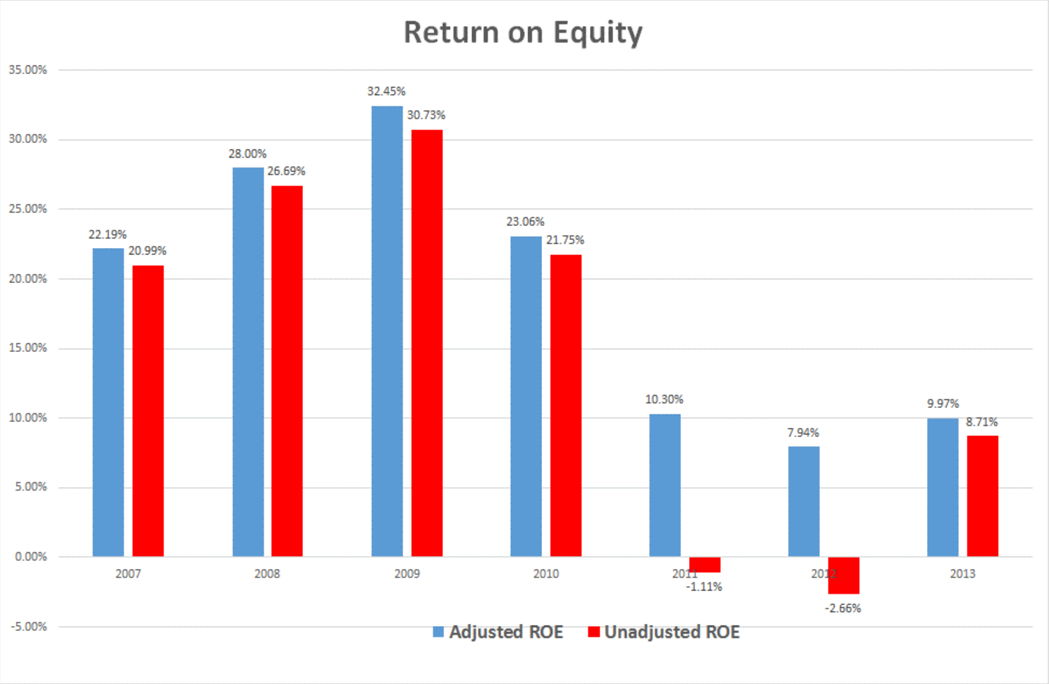
For companies that can remain in this powerhouse square, value, the P/E ratio, the EV/EBITDA ratio and the market to book ratio are highest. This is illustrated in the graph of simulation results below. The real issue in the graph is the difficulty of getting to the power house square where you can grow a lot faster than the overall economy and at the same time earn high returns. Staying in the power house square for a long time when other companies from all over the world are trying to enter the industry is an even bigger problem. Before 2010, First Solar seemed to be a classic power house company. In 2008 it had a P/E ratio of 51 times and its stock price had reached $314 per share. This stock price was relative to a book value per share of $18.5 and the IPO price in 2006 of $20 per share. It was without doubt a fast growing company in a fast growing industry. At the same time, First Solar was generating very high returns. First Solar was earning a return of above 30% between 2006 and 2009 as shown below. You do not have to make fancy estimates of the beta to judge that a 40% return is above the cost of capital.

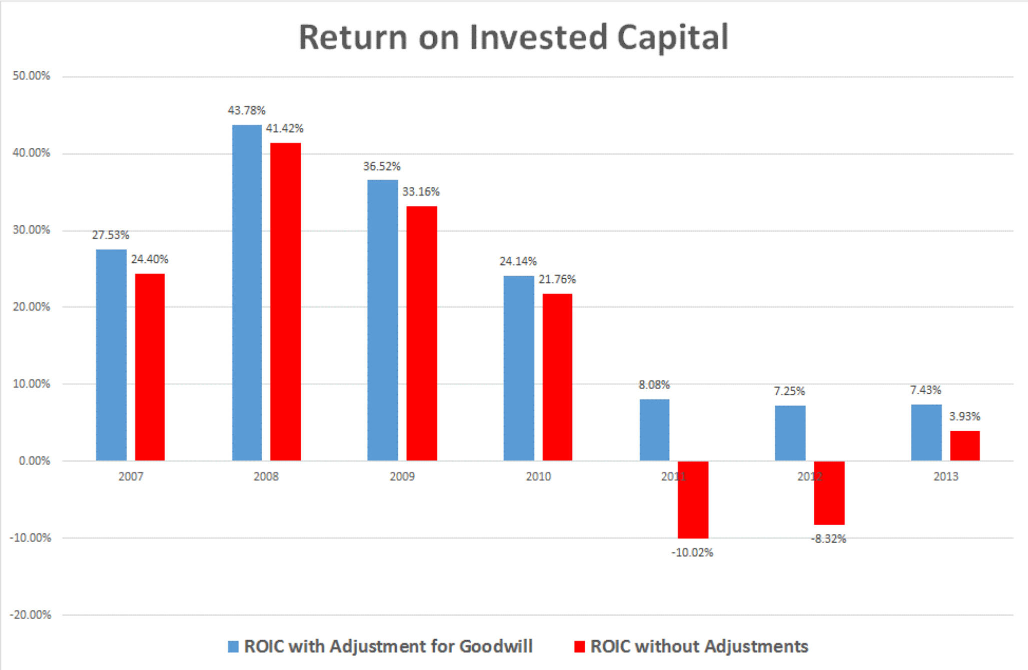


The fundamental issue with assessment of the value of First Solar and the common valuation error made for companies in the powerhouse square is that everybody else wants to be in the same place. Unless there is something very special that limits other companies from entering the business, time in this square can be short. Motorola was surely in the square when it came out with a portable phone. But it was quickly replaced by Nokia and then Blackberry, followed by Apple and Samsung. From a very basic economic perspective, when new companies enter into industries with companies in the powerhouse square, industry supply increases. After industry supply goes up, which can be sudden and extreme, surplus capacity becomes a problem, prices can decline to marginal cost very quickly and returns drop through the floor. Even without surplus capacity, the desire to enter into the powerhouse square attracts companies that have low cost structure who can effectively compete. This is what is supposed to happen in capitalist economies to push prices to long-run marginal cost. These days with a globalized economy, the competitors could come from anywhere. The most basic question about First Solar that should have been addressed by investors was whether it had a real unique competitive advantage and whether it could maintain the high returns in the face of companies that were entering the business from China.

First Solar’s Rate of Return

The return on equity for First Solar shown below measures the amount of money accruing to shareholders relative to their investment. It includes the effects of financing and activities related to non-core operations. The return on invested capital displayed on the subsequent chart only reflects the rate of return earned on the fundamental business in manufacturing solar panels and developing solar projects, at least in theory. Return on invested capital is in theory a better measure to use in assessing trends in profitability of the core business activities, but it is more subjective to compute. A difficult problem in calculating return on invested capital is how to treat items that reduce investment on the balance sheet, but do not involve any returns to investment. The difference in measured returns with and without adjustments shown in both figures. Adjustments include factors such as goodwill impairment that reduce invested capital, but are not cash outflows and thus do measure the amount of money contributed by investors.





With hindsight, the returns earned by First Solar were not sustainable. Returns like those earned in 2009 and 2010 shown above led to a lot of expansion, surplus capacity and competitive pressure. A central question in the valuation process for First Solar should have been whether the declines in the rate of return on invested that occurred were predictable. For example, even if First Solar did have some kind of unique manufacturing process, valuation analysts should have understood that this process could ultimately have been copied. The ultimate policy proposition of programs like the German FIT was to reduce prices. If companies such as First Solar were earning very high returns, the savings were not being passed on the consumers.

Failure to Evaluate Forecasts by Directly Evaluation Returns

Many corporations that have grown in importance in the 21st century ranging from Amazon to Uber to Comcast are close to being unregulated monopolies. Companies seem to attain a certain size and control anything from access to information to labour resources to distribution that make it highly difficult for new entrants to compete. The rate of return on investment for these corporations can increase to high levels for a long time. Returns can remain at high levels because the companies have succeeded preventing new entry into their part of the industry. For these corporations, forecasts generally involve projecting revenue growth operating costs required to sustain the growth. In the case of more traditional businesses ranging from small restaurants to transport companies to manufacturing, however, understanding and evaluating financial forecasts through evaluating whether the rate of return is still an essential verification of the analysis. In the case of solar manufacturing in 2010 and earlier, many firms were in the industry and entry was certainly possible. Evidence of the ease of entry was the requirements of countries like Brazil to have locally produced content a large part of the project cost.

In valuing corporations such as First Solar, the process generally involves projecting financial statements over a period and then valuing the company from statistics in the final period of the forecast that are intended to represent sustainable and stable values that can be maintained indefinitely. An example of such a valuation are forecasts made by Value Line Investment survey.[13] When First Solar's stock price was $124 per share in July 2011, Value Line Investment Survey expected the earnings to double from $7.68 per share to $14.85 per share and forecast the P/E ratio to rise to 25 as shown in the excerpt below. Multiplying the projected earnings per share by the P/E ratio implied an average target price of $372.25 (you can see the high and the low target of $295 and $445 at the bottom left). In contrast to the earnings per share forecast of $14.85, actual earnings in 2014 were $3.97 and using the average stock price over the year of $42.32, the implied training P/E ratio was 10.66 rather than the forecast of 25 times. The average stock price of $42.32 in 2014 compares to the predicted price of $375.25. To say the least, the valuation was a bit wrong. Enough said.

FIRST SOLAR, INC. NDQ-FSLR | RECENT PRICE **124.65** | P/E RATIO **13.3** (Trailing: 17.8 Median: NMF) | RELATIVE P/E RATIO **0.82** | DIV'D YLD **Nil** | VALUE LINE

First Solar was founded in 1999 with the goal of applying new technologies to the process of solar power generation. The company initially conducted only research and development operations, until commercial operations began in January 2002. The company went public in November 2006, issuing 22.9 million shares at $20 each, in a deal underwritten by Credit Suisse and Morgan Stanley.

2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	© VALUE LINE PUB. LLC	14-16
--	--	--	--	1.06	1.87	6.41	15.27	24.24	29.86	*42.50*	*53.65*	Sales per sh A	*84.20*
--	--	--	--	d.07	.20	1.73	5.00	9.03	9.55	*11.60*	*13.15*	"Cash Flow" per sh	*17.40*
--	--	--	--	d.14	.07	1.43	4.24	7.53	7.68	*9.40*	*10.70*	Earnings per sh A B	*14.85*
--	--	--	--	--	--	--	--	--	--	*Nil*	*Nil*	Div'ds Decl'd per sh	*Nil*
--	--	--	--	.94	2.12	3.08	5.63	3.28	6.86	*12.50*	*6.75*	Cap'l Spending per sh	*9.45*
--	--	--	--	.29	5.69	13.96	18.54	31.13	40.25	*48.50*	*58.65*	Book Value per sh	*81.20*
--	--	--	--	45.21	72.33	78.58	81.60	85.23	85.84	*88.00*	*89.00*	Common Shs Outst'g C	*95.00*
--	--	--	--	--	NMF	73.1	50.7	19.3	16.5	*Bold figures are*		Avg Ann'l P/E Ratio	*25.0*
--	--	--	--	--	NMF	3.88	3.05	1.29	1.06	*Value Line estimates*		Relative P/E Ratio	*1.65*
--	--	--	--	NMF	.9%	9.8%	20.9%	23.0%	18.1%	*18.0%*	*17.5%*	Return on Total Cap'l	*17.5%*
--	--	--	--	NMF	1.0%	10.2%	23.0%	24.1%	19.2%	*19.0%*	*18.0%*	Return on Shr. Equity	*18.0%*

2014-16 PROJECTIONS

	Price	Gain	Ann'l Total Return
High	445	(+255%)	37%
Low	295	(+135%)	24%

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[13] The forecasts can be obtained from www.valueline.com. An evaluation of Value Line forecasts is included in the www.edbodmer.com website.