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The prospects for cost competitive solar PV power ☆

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HIGHLIGHTS

- ▸ Assessment of the cost competitiveness of new solar Photovoltaic (PV) installations.
- ▸ Utility-scale PV installations are not yet cost competitive with fossil fuel power plants.
- ▸ Commercial-scale installations have already attained cost parity in certain parts of the U.S.
- ▸ Utility-scale solar PV facilities are on track to become cost competitive by the end of this decade.

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ABSTRACT

New solar Photovoltaic (PV) installations have grown globally at a rapid pace in recent years. We provide a comprehensive assessment of the cost competitiveness of this electric power source. Based on data available for the second half of 2011, we conclude that utility-scale PV installations are not yet cost competitive with fossil fuel power plants. In contrast, commercial-scale installations have already attained cost parity in the sense that the generating cost of power from solar PV is comparable to the retail electricity prices that commercial users pay, at least in certain parts of the U.S. This conclusion is shown to depend crucially on both the current federal tax subsidies for solar power and an ideal geographic location for the solar installation. Projecting recent industry trends into the future, we estimate that utility-scale solar PV facilities are on track to become cost competitive by the end of this decade. Furthermore, commercial-scale installations could reach “grid parity” in about ten years, if the current federal tax incentives for solar power were to expire at that point.

1. Introduction

New installations of solar photovoltaic power have experienced rapid growth in recent years. In 2010 alone, almost 17 GW of new photovoltaic (PV) power was installed worldwide. This addition not only represented a 250% increase relative to 2009, it was also roughly equal to the total *cumulative* amount of solar PV power installed since the commercial inception of solar PV technology in the 1970s.[1] While the impressive growth rates for new solar energy deployments are uncontroversial, there is considerable disagreement regarding the economic fundamentals of this energy source. In particular, there appears to be no consensus as to whether solar PV power is approaching *grid parity*, which would require the cost of solar photovoltaic generated electricity to be on par with that generated from other energy sources, including fossil fuels such as natural gas or coal.

Proponents of solar power see the rapid growth of the solar PV industry and the dramatic drop in the price of panels as evidence of increasing competitiveness of this energy source. In contrast, skeptics attribute the rapid rise of solar PV power primarily to generous public policies in the form of tax subsidies and direct mandates for renewable energy. Furthermore, this camp in the public debate argues that the precipitous decline in solar panel prices is not a reflection of favorable economic fundamentals, but rather reflects distress pricing caused by massive new entries into the solar panel manufacturing industry. As further evidence of lacking economic fundamentals, the skeptics point out that the equity market value of virtually all solar panel manufacturers has imploded in recent years.

This paper provides an assessment of the cost competitiveness of electricity generated by solar power. We first base this assessment on the most recently available data. In light of the dramatic

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[1] See, for instance, the 2011 BP Statistical Review of World Energy. For 2011, newly installed capacity of solar PV is estimated to be near 29 GW.

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price reductions that solar PV panels have experienced in recent years, we also seek to extrapolate the prospects for further cost reductions that could be obtained with currently available technology. This part of our analysis speaks to the question of whether a continuation of the significant learning-by-doing process that has characterized this industry is likely to result in 'grid parity' in the foreseeable future without the need for a technological breakthrough. Our analysis also examines the sensitivity of our cost assessment to several crucial input variables, such as panel prices, geographic location of the facility and public subsidies in the form of preferential tax treatment.

The central cost concept in this paper is the *Levelized Cost of Electricity* (LCOE). It represents a life cycle cost per kilowatt hour (kWh) and is to be interpreted as the minimum price per kWh that an electricity generating plant would have to obtain in order to break-even on its investment over the entire life cycle of the facility. This break-even calculation essentially amounts to a discounted cash flow analysis so as to solve for the minimum output price required to obtain a net-present value of zero. Unfortunately, the method used for calculating the LCOE in the literature is far from uniform. We discuss this aspect in more detail in Section 2 below and in Appendix A2.[2]

With regard to PV technology platforms, our analysis covers both the more established crystalline silicon and so-called thin-film solar cells. Crystalline silicon cells are known to be more efficient in terms of the potential energy converted to electricity. Yet, efficiency of the cell is not a criterion per se in our cost analysis as differences in efficiency are subsumed in both input cost and electricity output figures. In terms of the scale of electricity generation, we consider both utility-scale installations (commonly defined as those larger than 1 MW) and installations of commercial scale (in a range of 0.1 to 1 MW). The latter installations would typically be mounted on large rooftops of office buildings and warehouses. While smaller commercial-scale installations cannot attain the full scale economies of utility-scale projects, the benchmark of grid parity is also more lenient to the extent that the applicable cost needs to be compared with retail electricity prices for commercial users rather than wholesale prices at the utility-scale level.

Our point estimates for the Levelized Cost of solar PV electricity are based on favorable, albeit realistic scenarios. In particular, we assume that the electricity generating entity can procure solar panels and other equipment components at the lowest transaction prices observed in the market in late 2011. We also assume that the investor in the solar PV project can benefit from the federal incentives available for these types of projects in the United States—namely a 30% investment tax credit and an accelerated depreciation schedule. Furthermore the location of the facility is assumed to be an ideal one, for instance, in the southwestern United States. The favorability of a location is defined both in terms of insolation and systems degradation, that is, the decay over time in the electricity output of a solar cell.

We find that that crystalline silicon enjoys a slight cost advantage over thin-film, though the two appear generally neck-and-neck for all the scenarios we consider. At around 8 cents per kWh, we find that the LCOE of utility-scale installations is currently not cost competitive with electricity generation from fossil fuels, in particular from natural gas plants. In contrast, at around 12 cents per kWh, commercial-scale installations appear to have reached grid parity, at least in locations like Southern California that are both geographically favorable for solar installations and subject to high retail electricity prices. Given that this appears to be the most favorable scenario for solar PV, we use it as the reference case for further comparisons throughout the paper.

The conclusions we obtain for utility-scale projects suggests that the recent growth in such installations is in large part a consequence of additional public subsidies or government mandates for renewable energy. The Renewable Portfolio Standard in California represent such a mandate, while countries like Germany rely on 'feed-in-tariffs' which oblige grid operators to buy solar electricity at pre-specified prices.[3]

Our conclusion of grid parity for commercial-scale solar PV is shown to be highly dependent on several crucial assumptions. First, absent the current tax subsidies under the Economic Stabilization Act of 2008, our LCOE estimate would increase by over 75%. Secondly, if the power generating facility were to be located in New Jersey rather than Southern California, the applicable LCOE estimate would increase by about 25%. Third, the dramatic recent drop in solar panel prices, in particular the 40% drop in 2011 alone, is likely to be a temporary artifact caused by excess production capacity in the solar PV panel industry. Based on the observed long-term price trend for PV modules, we form an estimate of 'sustainable' panel prices. We estimate that if solar panel prices were priced today at the levels suggested by their long-term price trend, our LCOE figures would increase by about 12–15%.

In examining the sensitivity of our cost estimates to these factors, it should be noted that collectively these factors have a 'super-modular' effect on the resulting cost estimate. To witness, for a facility based in New Jersey that would have to acquire PV modules at sustainable prices and whose tax treatment is identical to those of fossil fuel electricity generating plants, the estimated LCOE would increase by about 150% relative to our baseline reading of 12 cents per kWh.

Since its inception in the 1970s, prices of solar panels have fallen at a rate that is remarkably consistent with the traditional 80% learning-by-doing curve. As documented by Swanson (2006, 2011) the market prices for solar panels have on average declined by approximately 20% every time the cumulative volume of solar PV power installations has doubled. Swanson provides evidence that a range of variables related to thinner silicon wafers, higher semiconductor yields, improvements in the efficiency of the solar cell and other manufacturing process improvements have all contributed to substantial and sustained cost reductions. These reductions in cost have, in turn, translated into corresponding price reductions.

If one postulates the continuation of the established learning curve for photovoltaic modules in the future, it is natural to ask how long it would take current technology—continuously optimized over time—to become fully cost competitive. In making this projection, we assume that in the future crystalline silicon modules will indeed be able to maintain the 80% learning factor they have experienced consistently over the past 30 years. Yet, this pace of learning appears too optimistic for so-called Balance-of-Systems (BoS) components related to cabling, wiring, racking, and permitting. For these BoS costs, which presently account for more than half of the total systems price of new solar installations, we hypothesize a constant percentage reduction each year rather than the exponential learning curve applicable to modules.

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[2] Our interpretation of cost competitiveness is that for the party investing in a solar PV facility the levelized cost per kWh, after inclusion of all tax benefits, does not exceed the applicable grid price. The latter varies depending on whether the investing party seeks to sell the electricity output to a distributor at wholesale prices, or whether it seeks to avoid the retail price of electricity that it would have pay for its own consumption.

[3] The Renewable Portfolio Standard in California commits the state to a quota of generating at least 33% of all electricity from renewable energy sources by the year 2020.