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# An Economic Analysis of Photovoltaics Versus Traditional Energy Sources: Where Are We Now and Where Might We Be in the Near Future?

## Preprint


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# AN ECONOMIC ANALYSIS OF PHOTOVOLTAICS VERSUS TRADITIONAL ENERGY SOURCES: WHERE ARE WE NOW AND WHERE MIGHT WE BE IN THE NEAR FUTURE?

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## ABSTRACT

A precipitous drop in the price of the crystalline silicon solar photovoltaic (PV) modules typically employed for residential applications has recently been observed: The typical sales price for modules was around \$4/$W_{P\ DC}$ in 2008 but could easily approach \$1.50/W $W_{P\ DC}$ by the end of this year[1]. As module price declines continue, and as gains are also realized in balance-of-system costs, the economics of PV systems for power generation become increasingly competitive. In this presentation, we will examine whether solar will reach grid parity in the United States if monocrystalline silicon modules achieve an optimistic-case scenario in efficiency and cost. The analysis suggests that PV systems are already economically viable in select markets, but further cost reductions and efficiency improvements above and beyond the monocrystalline optimistic-case scenarios are necessary in order to be competitive against incumbent electricity production in most markets across the United States.

## ANALYSIS

In close consultation with U.S.-based residential PV installation firms, NREL has constructed a detailed analysis of PV system prices[2]. In this system, it is assumed that the available residential rooftop area (35 $m^2$) can accommodate 21 standard size (1.64 $m^2$) monocrystalline silicon PV modules. With 14.5% efficiency for each module—meant to represent the current typical industry average and not necessarily the "best in class"—the modeled system size is 4.9 $kW_{P\ DC}$. The results of the analysis for a typical monocrystalline silicon solar installation are shown below in Figure 1.

This analysis is based upon national average labor rates, and an understanding of the time required to install each component in the system's bill-of-materials (BoM), to arrive at an estimate for the labor costs of the installation. Overhead costs (including permitting, grid connection, sales taxes, installer operating overhead and profit margin, etc.) are based upon values most often reported by collaborating installers.

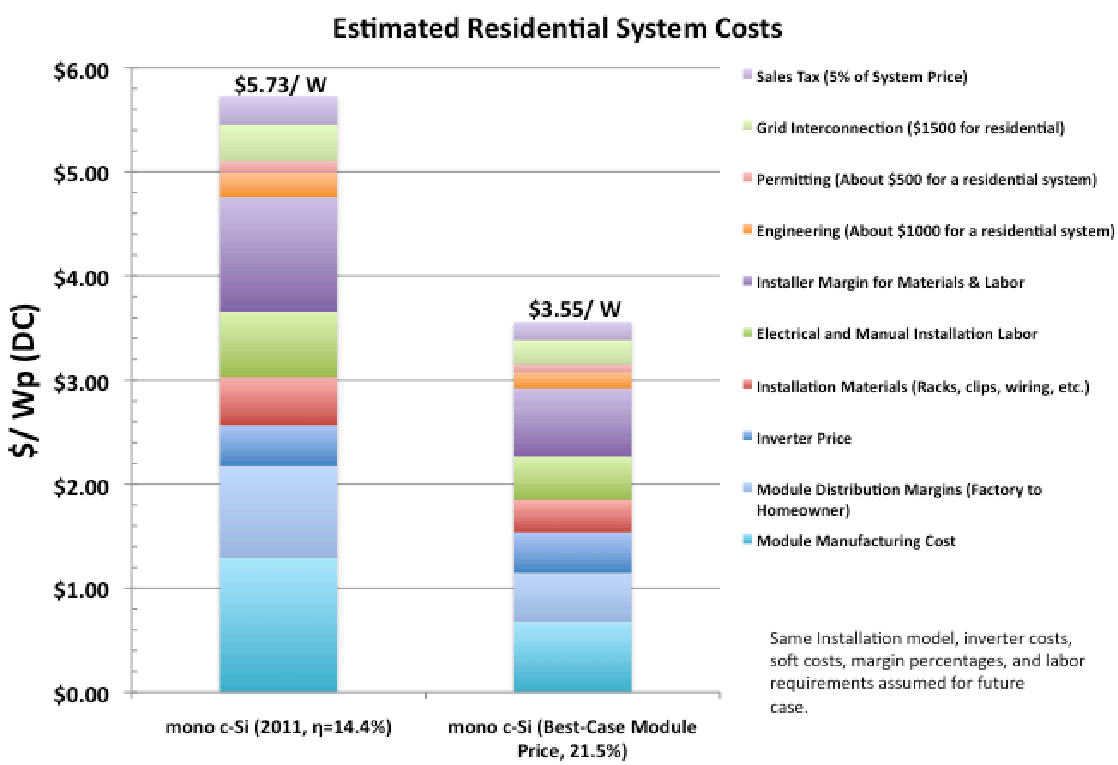


**Figure 1 Estimated costs for residential PV systems installed in the United States: current (left) and a modeled system with lower-cost and higher-efficiency modules (right) as described in the text. Source: Goodrich et al[2].**

We estimate the optimistic-case future price for monocrystalline-silicon modules to be $0.68/W_{P\ DC}$. This estimate is based upon a wafer thickness of 80 µm (kerfless) with $32/kg polysilicon[3]; the cell processing costs are based upon interdigitated back contact (IBC) architecture, standard module materials (glass front, EVA, standard wafer interconnections, etc.), and a module efficiency of 21.5%. Using this module without any changes to the installation BoM costs or methods—quite arguably a conservative assumption—the resulting system costs may be reduced from around $5.70/ $W_{P\ DC}$ to around $3.50/$W_{P\ DC}$.

These system costs can be used to estimate the levelized cost of electricity (LCOE) for the system[4]:

$$\text{LCOE (\$/ kWh)} = \frac{\text{Total Life Cycle Cost (\$/ W}_p\text{)}}{\text{Total Lifetime Energy Production (kWh/ W}_p\text{)}}$$

$$= \frac{\text{Initial Investment } + \sum_{n=1}^{N} \frac{\text{Annual O \& M Costs}_n}{(1+\text{Discount Rate})^n} - \sum_{n=1}^{N} \frac{\text{Depreciation}_n}{(1+\text{Discount Rate})^n} \text{x(Tax Rate)}}{\sum_{n=1}^{N} \frac{\text{Rated kWh/ W}_p \text{ x Capacity Factor}}{(1+\text{Discount Rate})^n} \text{x(1 - System Degradation Rate)}^n}$$

For a residential rooftop system, there are typically only two scheduled operating and maintenance (O&M) events. The first is an end-of-year-one check of the system by the installer, which takes about two hours. The second event consists of a standard 10-year inverter replacement that requires around four hours of labor. The depreciation benefit can only be realized for leased systems; however, the leased system LCOE is not expected to be significantly different from that of system financed by the homeowner using a standard mortgage loan because the investor-backed discount rate is generally significantly higher for the leased systems (approximately 12% vs 7%) and because leased solar projects must also pay taxes on the electricity that is generated and sold.

If PV systems were able to produce electricity at the same price as that produced by predominately fossil fuel based sources, their deployment would be expected to increase. This price goal can be significantly different across the globe; furthermore, due to differing solar irradiation profiles and intensities, different deployment sites for a PV system are expected to return very different expectations of LCOE, even if the system price were the same. Figure 2

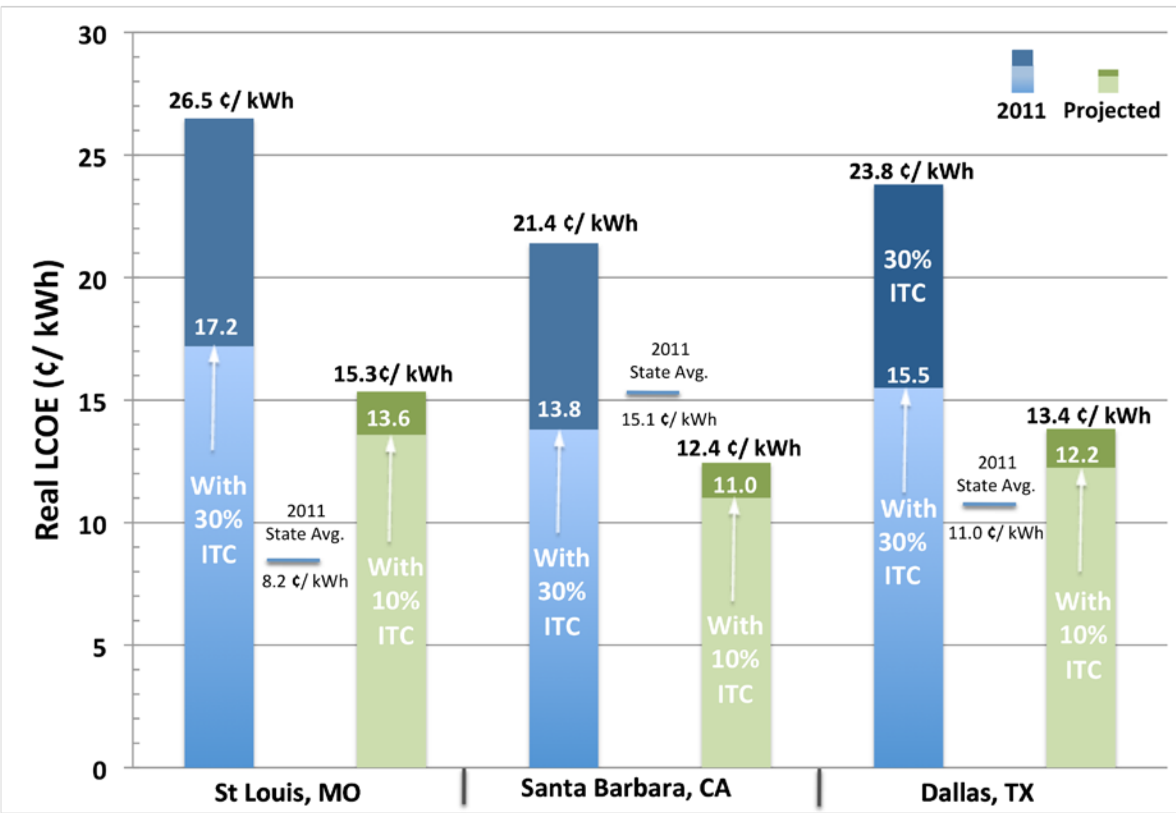


**Figure 2: Levelized Cost of Electricity (LCOE) estimates from NREL's Solar Advisory Model for residential PV systems deployed at three locations in the US. These estimates are based upon the same system price ($/$W_{p\ DC}$) in each location. The tallest bars in blue represent 2011 costs: the estimated LCOE with the current federal investment tax credit (ITC) of 30% is shown in white, while the fully unsubsidized cost estimates are indicated in black. The green bars represent the corresponding future case after system costs are reduced along the technology pathway described in the text; the LCOE at a 10% ITC subsidy level is shown for the future case as the sunset date for the 30% benefit is 2016 (after which systems are still set to receive a 10% ITC under current federal tax law). For comparison to convential electricity prices, the EIA's estimates for January 2011 average residential electricity rates within the respective states are indicated by the solid horizontal bars.[5]**

shows our estimates of LCOE, with and without the federal investment tax credit (ITC), for the 2011 and the future silicon module (price, efficiency) cases and compares them to residential electricity rates within the respective states. The 30% ITC used in 2011 differs from the 10% ITC used in the future case because the ITC will revert to the lower level in 2016. While deployment in certain “transitional” markets-- such as California-- already appears to be at price parity with statewide average electricity rates, and compares even more favorably when looking at the tiered pricing structures used throughout that state, most of the power generated in the United States is currently available at a lower cost than can be expected from the PV technology system described here. Because the majority of residential systems are based upon this technology, it is clear that advances in system costs (particularly in the non-module categories) are needed in order for PV to become competitive at an unsubsidized level across the United States.

## REFERENCES

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[4] Campbell, M. ; Blunden, J.; Smeloff, E.; Wright, S.; *The Drivers of the Levelized Cost of Electricity for Utility-Scale hotovoltaics*; SunPower Corporation: 2008.

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