Institute *for* Policy Integrity

new york university school of law

Annual Energy Outlook Projections and the Future of Solar Photovoltaic Electricity

By Noah Kaufman

Working Paper No. 2014/4

ANNUAL ENERGY OUTLOOK PROJECTIONS AND THE FUTURE OF SOLAR PHOTOVOLTAIC ELECTRICITY

NOAH KAUFMAN*

The Economist recently declared that due to technological advancements in solar photovoltaic (PV) energy, soon "alternative energy will no longer be alternative." But this transition to a solar energy future in the United States is rife with uncertainty. Will costs continue to fall at their recent pace? Can solar compete everywhere, or only when and where the sun shines brightest?

The lack of answers to these questions about the future of solar energy creates a problem for energy modelers. By their nature, models are built to reflect how a system currently works. Revolutionary changes are difficult to incorporate into models. However, proper policymaking requires accurate "baseline" energy forecasts. For example, the projected costs of retiring fossil fuel generating plants depend heavily on the ability of renewable sources like solar energy to take their places in the near future without causing large hikes in electricity prices.

The topic of this paper is the assumed growth of solar PV in current energy models, with a focus on information from the Annual Energy Outlook (AEO) reports of the U.S. Energy Information Administration (EIA), which report results from the most widely used and influential energy model in the country. EIA resolves the difficulty of modeling solar energy into the future by assuming its current growth will not continue. However, EIA's assumptions on the future costs of solar PV are highly pessimistic, and its methodology would appear to bias its "Reference Case" projections toward lower growth of solar energy. Sure enough, past AEOs have systematically underestimated the future growth of solar PV. Energy modelers therefore may need to adjust the AEO forecast in order to reflect a most likely baseline trajectory for solar PV.

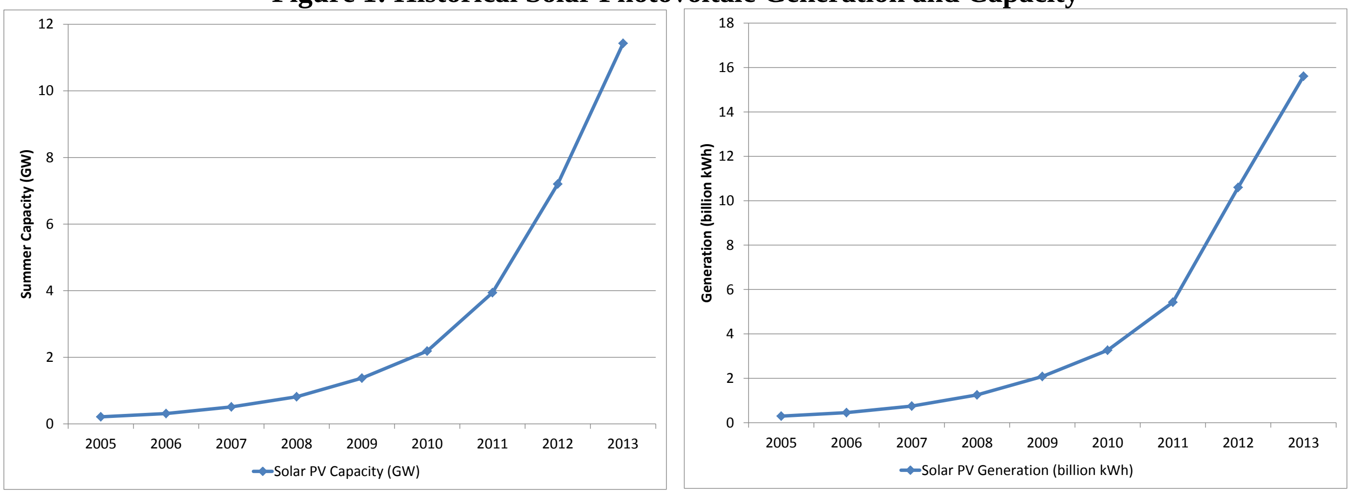
---

* Dr. Noah Kaufman is a Senior Consultant in the Environment Group of NERA Economic Consulting, based in Boston. This paper does not purport to represent the views of NERA Economic Consulting or New York University School of Law.

A. The Recent Growth of Solar Photovoltaic

Viewed in isolation, solar PV has experienced remarkable growth in recent years. Figure 1 shows that over the past decade, growth in solar PV electricity capacity and generation has been over 60 percent per year.

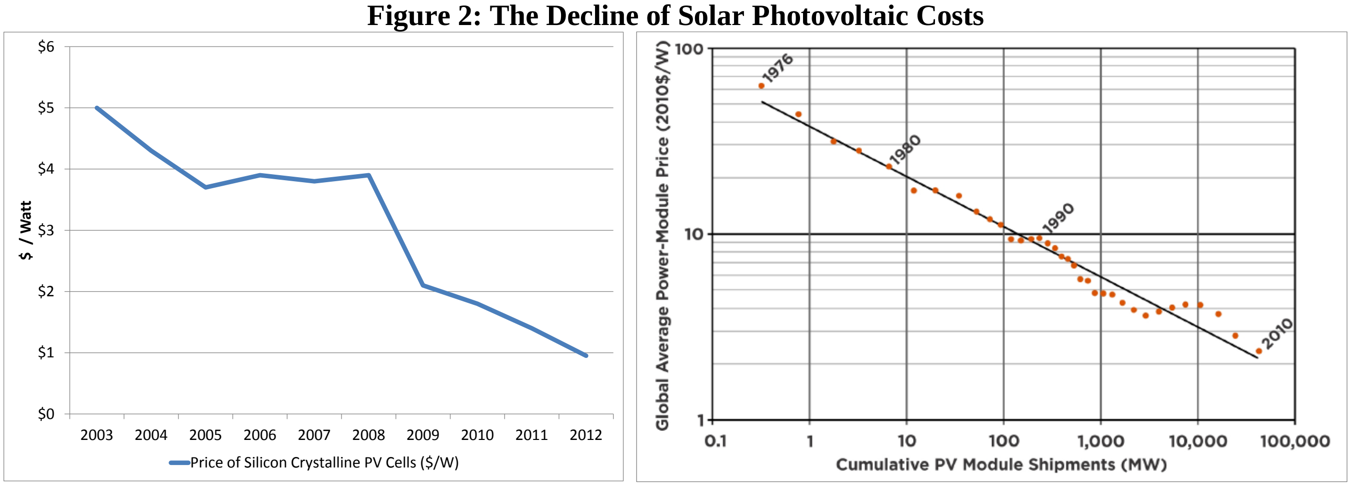
Figure 1: Historical Solar Photovoltaic Generation and Capacity



Sources: EIA (2008, 2009, 2010, 2011, 2012, 2013a, 2013b)

This growth is primarily due to the rapid decrease in the cost of solar cells, which comprise the vast majority of the costs of generating electricity from solar. The left side of Figure 2 shows that the cost of crystalline silicon PV cells has fallen by roughly 85 percent over the past decade. It is well recognized that the decrease in cost and the increased experience with solar PV go hand-in-hand. Over the past four decades, solar PV costs have followed what is referred to as "Swanson's Law" (named after the founder of a solar panel manufacturer), with module prices falling 20 percent with each doubling of global production, displayed on the right side of Figure 2.

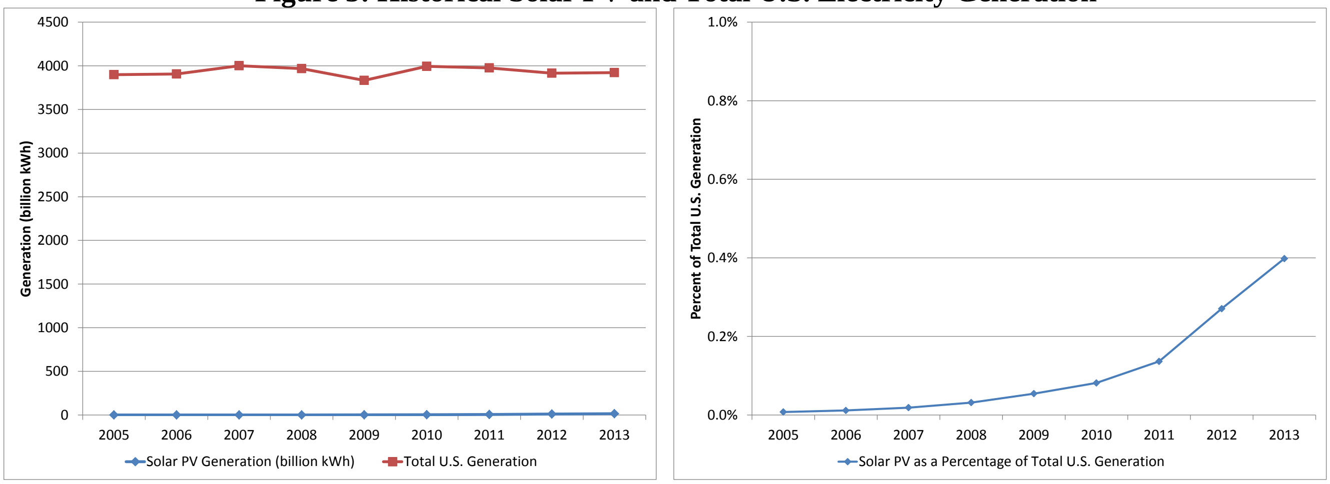
Figure 2: The Decline of Solar Photovoltaic Costs



Sources: Silicon crystalline PV cell prices are estimates based on Bloomberg, New Energy Finance graph from The Economist (2012); graph with global module prices and shipments is reproduced from DOE (2012).

However, some perspective is needed. Solar PV remains a very small portion of the U.S. energy sector as a whole. Figure 3 shows that solar PV remains under one percent of total U.S. electricity generation.

Figure 3: Historical Solar PV and Total U.S. Electricity Generation

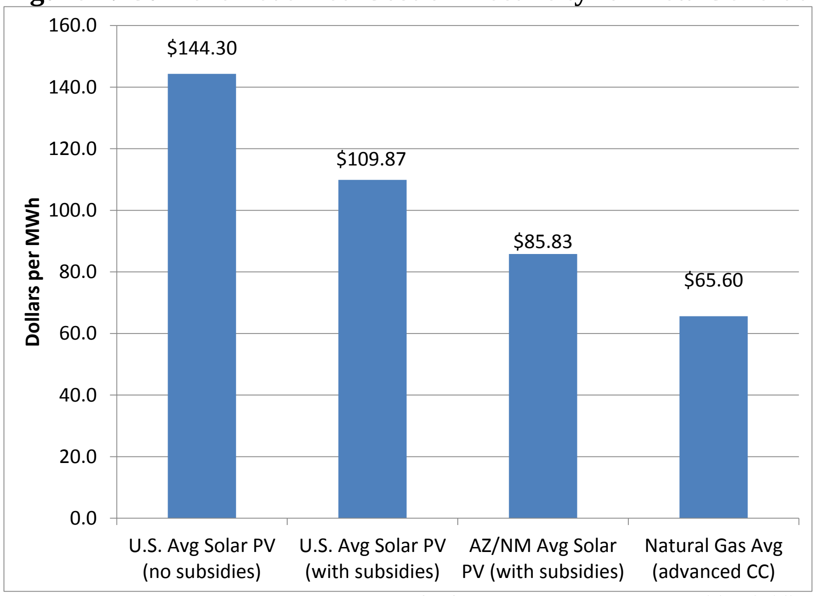


Sources: EIA (2008, 2009, 2010, 2011, 2012, 2013a, 2013b)

The low penetration of solar PV is primarily due to its cost (the intermittency of solar energy is also a concern, but not one that keeps generation below one percent). It can be misleading to compare the "average cost of solar" to alterative options because of the heterogeneity in solar PV costs for different regions of the country and for different types of installations. However, it is still informative to see the EIA estimates of the average levelized cost[†] of a (utility-scale) solar PV plant compared a new natural gas plant, which is displayed in Figure 4. Despite the cost improvements noted above, the costs of building and operating a natural gas plant typically remain far lower than the costs for an average solar PV plant.

[†] The "levelized cost of electricity" is the average price at which electricity must be generated over the lifetime of a generating plant such that the present value of the plant's total revenues and costs are equal.

Figure 4: Current Levelized Cost of Electricity for New Generation Resources ($/MWh)



Note: Per EIA, current new generation costs are for facilities installed in 2018; "with subsidies" cases assume tax credits at current levels.
Source: EIA (2013a)

Nevertheless, the differences in costs between solar PV and alternatives have decreased substantially over the past decade. In various regions of the country (e.g. California), the costs of subsidized roof-top solar panels are the most cost effective option for consumers. In other parts of the country, the cost of building utility-scale plants are much closer to the cost of new natural gas plants (Figure 4 shows the average cost in Arizona/New Mexico).

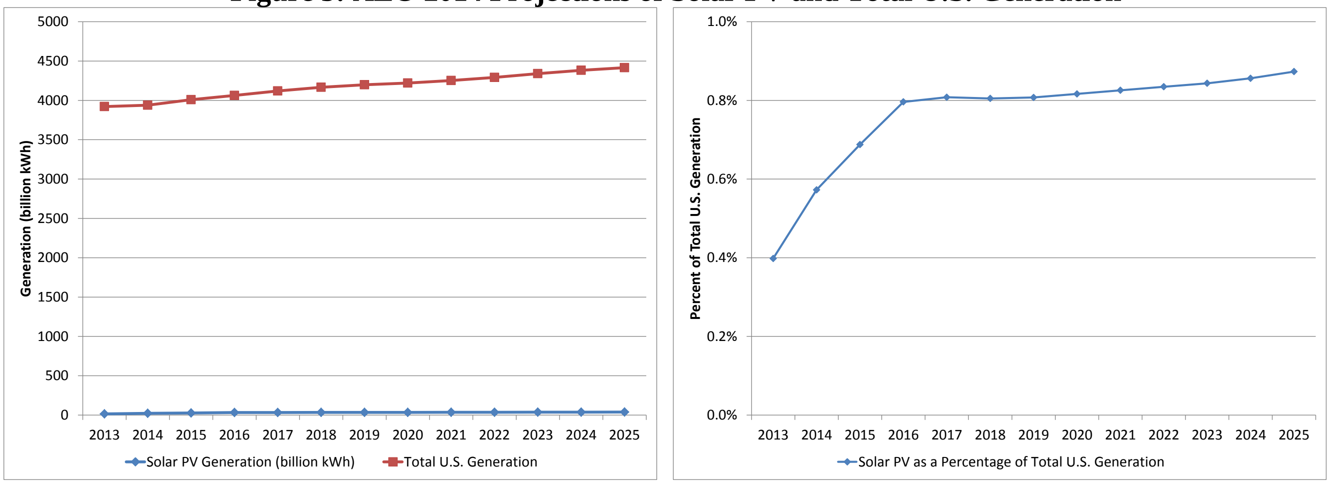
If "Swanson's Law" continues to lead to cost reductions, solar PV is likely to become even more competitive with natural gas in the near future. This leads the main questions of this paper: are energy models forecasting that this "grid parity" will be achieved? If so, will this lead to a "tipping point" whereby solar becomes a significant contributor to the electricity grid?

B. Projections of Solar Photovoltaic Electricity in the EIA Annual Energy Outlook

Each year, EIA releases its Annual Energy Outlook (AEO), which contains projections of the U.S. energy sector over the coming decades. These projections are important not only because they serve as the de facto "U.S. government energy forecasts," but also because energy modelers commonly use the AEO Reference Case as the starting point for their own modeling platforms and exercises.

As shown in Figure 5, AEO 2014 (from the "Early Release" published in December) projects that solar PV growth will slow considerably in the near future. Through 2025, solar PV is projected to remain less than one percent of total U.S. generation.

Figure 5: AEO 2014 Projections of Solar PV and Total U.S. Generation



Source: EIA (2013b)

This forecast implies that solar energy will not replace a significant amount of energy from fossil fuels in near future, which has major implications for the costs of environmental regulations. The near-irrelevance of solar energy in the AEO Reference Case forecast may come as a surprise to those expecting the continued ascent to prominence of solar energy in the near future. Coming from a U.S. government forecast this is particularly surprising, because the government has provided substantial support to solar in recent years.

However, a closer look at the assumptions underlying the AEO Reference Case modeling shows that there are various reasons to believe this forecast should not be considered a *most likely* projection:

- The cost of solar PV is projected to *increase* in the short-term, reversing the recent trend;
- Policies to promote solar are projected to *weaken*, reversing the recent trend; and
- Over the past decade, the AEOs have systematically under-estimated the growth of solar PV.

Each point is discussed below. Taken together, they suggest the EIA Reference Case should be viewed as a *pessimistic* scenario for solar PV growth in the near future, and that energy modelers should make adjustments to the AEO Reference Case to produce a *most likely* scenario for the growth of solar PV.

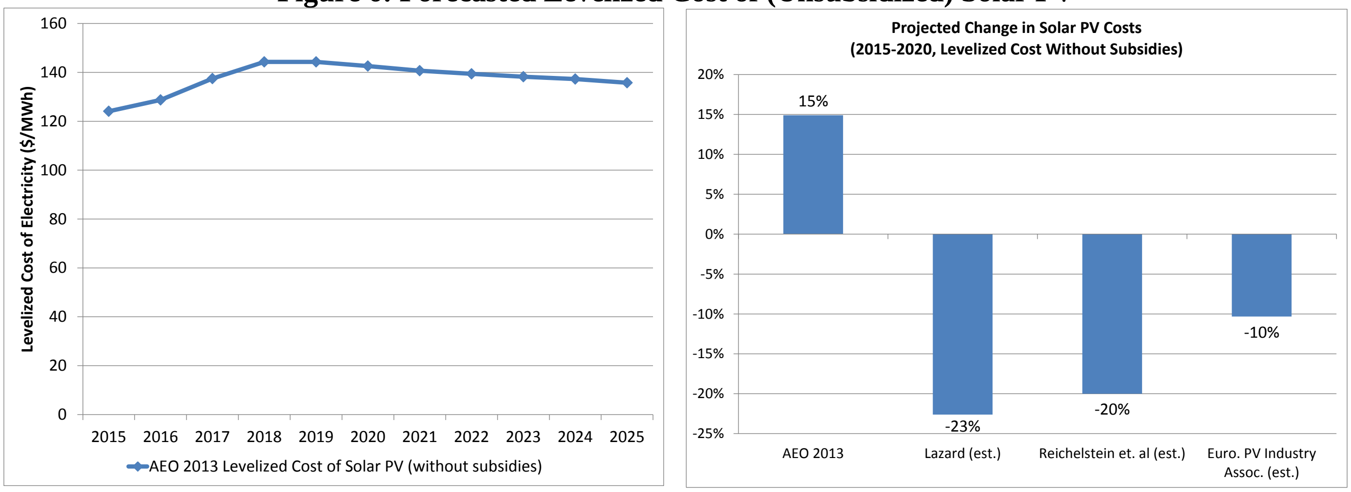
1. The Cost of Solar Photovoltaic Technology

As shown above, the cost of solar PV has fallen precipitously in recent years. In contrast, EIA projects the levelized cost of solar PV to increase in the near future, as shown in Figure 6 for AEO 2013 (before adjusting for any effects of subsidies). EIA does assume that the “overnight cost” of a solar installation will decrease modestly, but this is outweighed by other factors, the largest of which is a projected rise in interest rates, which increases the costs of financing solar installations.

Of course, projecting future technological advancements is an extremely uncertain science, but it is noteworthy that the EIA projection is at odds with both the trend of recent decades and other publicly available projections.

Figure 6 shows various (approximate) projections of cost trajectories from 2015 to 2020, from academia, industry and the private sector. All except the AEO forecast show a continued decline in solar PV costs.

Figure 6: Forecasted Levelized Cost of (Unsubsidized) Solar PV



Sources: EIA (2013a); Lazard (2011); Riechelstein et. al (2013); European Photovoltaic Industry Association (2012).

Changes in the cost of solar cells may be the key driver to changes in future levelized costs of solar energy, but there are other important factors that could also lead to solar energy surpassing the low-growth projections of the AEO Reference Case. For example, advancements in storage technologies could lead to increased output from solar installations, and thus lower costs per unit of capacity. The future of public policies to either promote solar generation or discourage fossil fuel generation may be an even more important factor, which is discussed in the next section.

2. Policies to Promote Solar Photovoltaic

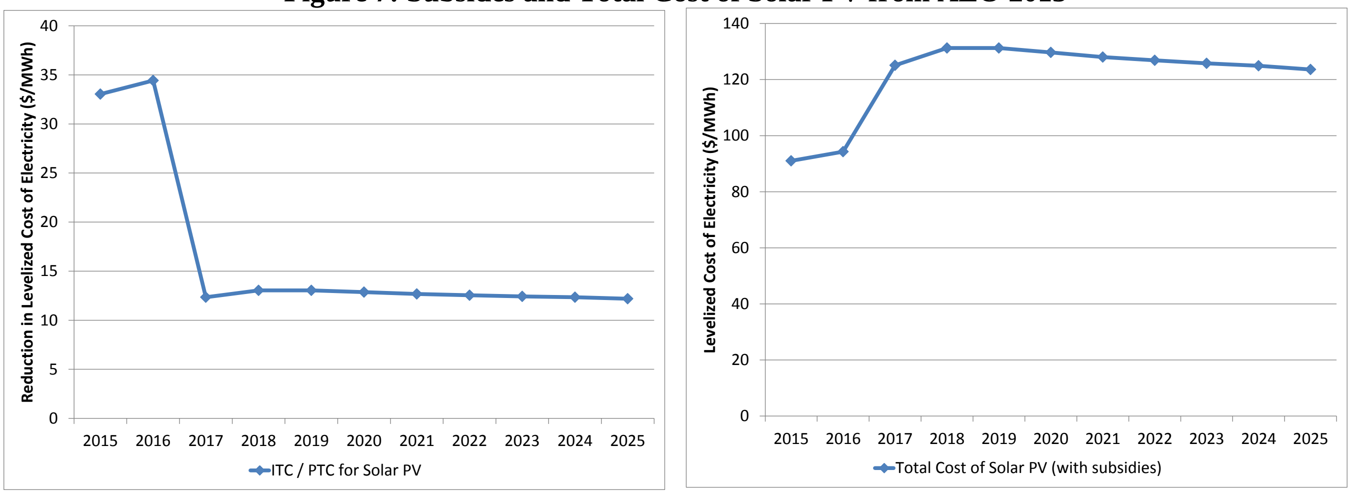
The AEO Reference Case is often misinterpreted as a *best guess* of the future U.S. energy sector. In reality, it reflects a forecast of the energy sector under currently-enacted policies. This is not a subtle difference—even if Law X is widely expected to be passed in the coming years, but it has not yet been passed, the effects of Law X will not be included in the AEO Reference Case.

This is relevant to solar energy mainly due to the federal investment tax credit (ITC), which provides developers with a 30 percent tax credit on solar energy properties. The current ITC is scheduled to expire at the end of 2016. The implication of the ITC expiration is displayed in Figure 7, which shows the total projected effects of subsidies on the levelized cost of solar PV in the AEO 2013 Reference Case. After decades of cost decreases, the total cost of solar PV is projected to jump over 20 percent in 2017 alone, which corresponds with the projected end of solar PV growth in the AEO Reference Case.

Of course, there are many conceivable public policy outcomes, and the outcome depicted in the AEO Reference Case is well within the realm of possibilities. However, it is a highly pessimistic assumption that would represent a reversal of recent trends. State and federal efforts to support the development of solar energy and to more heavily regulate fossil fuel energy have greatly expanded in recent years. In addition to the passage of the ITC in

2008, there is also a federal production tax credit, and many U.S. states have developed specific tax credits and requirements for certain levels of solar energy production (e.g. provisions in renewable portfolio standards).

Figure 7: Subsides and Total Cost of Solar PV from AEO 2013



Source: EIA (2013a)

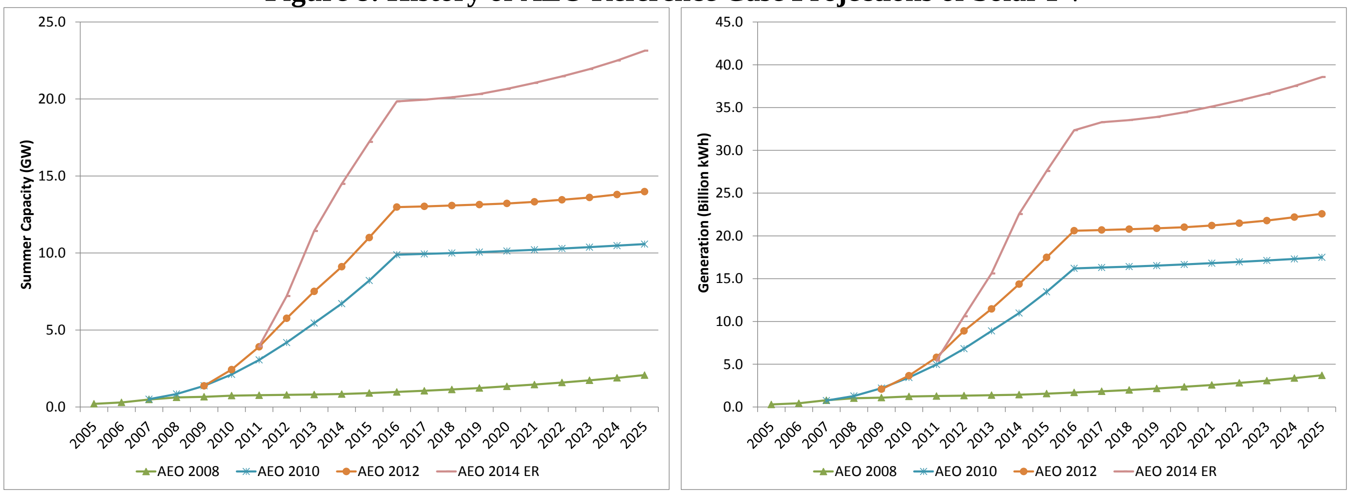
It therefore seems more likely that public policy support for solar energy will continue in some form. The ITC may be renewed or modified, or, if the current legislative stalemate in Washington D.C. continues, increases in state incentives may fill the void of an expiring ITC. Alternatively, climate change regulations or reductions in fossil fuel subsidies may increase the cost of coal and natural gas generation, thus reducing the relative cost of solar. Regardless, unless recent trends reverse, the methodology of the AEO Reference Case with respect to public policy will tend to show lower solar PV growth than should be anticipated under a most likely public policy trajectory.

This is not a criticism of EIA, which, to reiterate a point made above, does not intend for the AEO Reference Case to be a *most likely* scenario. For example, EIA is not *predicting* that the ITC will expire, it simply is following its general methodology of not assuming future policy changes. Indeed, the AEO 2013 report also includes a sensitivity analysis with projections that assume current policies such as the ITC do not expire (called the "No Sunset" case), and projections of solar PV growth are considerably higher for this modeling scenario.

3. History of Solar Photovoltaic Modeling in the Annual Energy Outlook

The relatively pessimistic assumptions EIA makes related to solar PV costs and public policy supporting solar PV suggest that the methodology would tend to underestimate the growth of solar PV. Sure enough, over the past decade, the AEOs have systematically needed to revise their solar PV growth projections upward to account for actual growth. Figure 8 shows the Reference Case projections of the growth of solar PV generation and capacity for AEO 2008, AEO 2010, AEO 2012 and the AEO 2014 Early Release.

Figure 8: History of AEO Reference Case Projections of Solar PV



Source: EIA (2008, 2010, 2012, 2013b)

However, while EIA has changed its forecast to reflect current realities, Figure 8 shows that it continues to project that this upward trajectory will flatten in the near future (for the reasons noted above). If, instead, solar cost and public policy trends do not reverse, a much different trajectory should be expected.

C. Alternative Modeling of the Growth of Solar Photovoltaic Energy

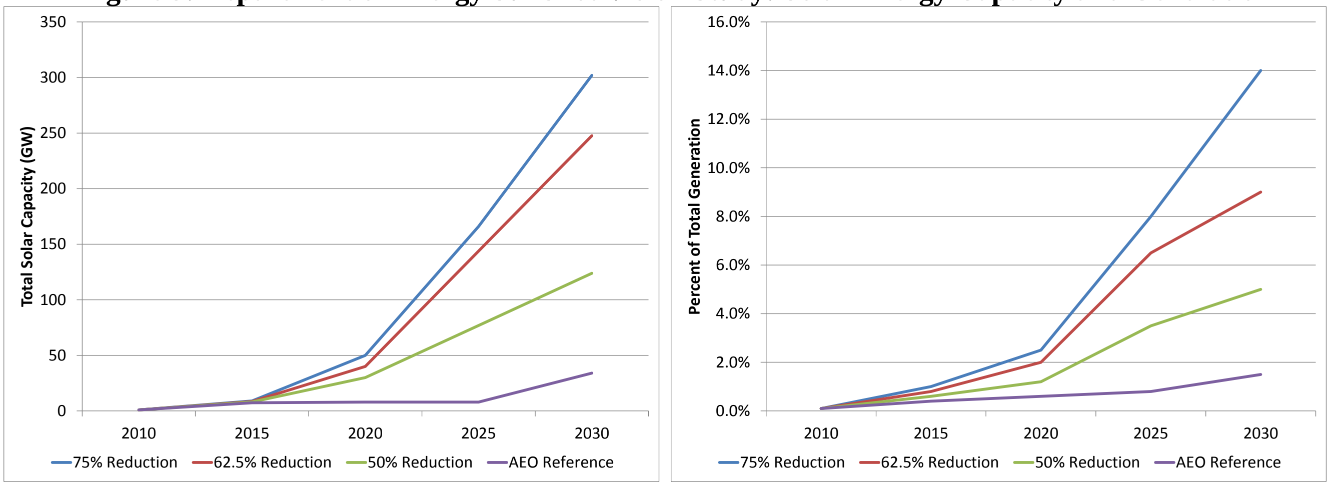
The preceding section showed that the methodology used by EIA tends to underestimate the growth of solar PV. A modeling exercise that may be more likely to produce reasonable growth trajectories was undertaken by the Department of Energy (DOE) in 2012, which modeled various potential trajectories for solar PV cost reductions.

The DOE *Sunshot Vision Study* modeled three cost reduction scenarios, with solar PV costs between 2010 and 2020 falling by: (1) 50 percent; (2) 62.5 percent and (3) 75 percent. These scenarios are not meant as “predictions,” but rather as representations of the energy sector assuming continuing reductions of solar costs at various levels. These are large cost reductions, but on a percentage basis they are far less aggressive than the cost reductions achieved in the recent past. The DOE models also assume that the federal investment and production tax credits are assumed to expire (and no other policies are enacted to compensate), so these are not best case scenarios for solar PV.

The three DOE scenarios and the comparable AEO Reference Case are displayed in Figure 9 (in this figure, concentrating solar power is included for both the EIA and DOE modeling, though the amount is small relative to the solar PV). The three DOE cost reduction scenarios show that by 2025, solar PV would represent between 3 and 8 percent of total U.S. electricity generation, and these percentages would climb to 5 to 15 percent by 2030.

None of these cases predict that solar PV will revolutionize the U.S. electricity grid in the near future. However, the use of any of these cases as an expected (or “baseline”) scenario is likely to significantly affect the estimated costs of environmental regulations. If solar PV is competitive with coal and natural gas by the early 2020s, then switching from fossil fuels to renewables will lead to lower electricity price increases than would be estimated using the AEO Reference Case as a baseline scenario.

Figure 9: Department of Energy SunShot Vision Study: Solar Energy Capacity and Generation



Source: DOE (2012).

D. Conclusions and Implications

If technological advancements and policy support for solar energy continue at their recent pace, solar energy is poised to reach “grid parity” with alternative options for electricity generation in the United States in the near future. When this will occur across the country and precisely what will happen when it does occur are difficult questions for energy modelers.

The Reference Case of the EIA Annual Energy Outlook is the country’s most prominent energy forecast, and it provides the inputs to energy models in use across the globe. The methodology of the AEO Reference Case leads to highly pessimistic projections for growth of solar PV. Energy modelers looking to depict a *most likely* scenario may need to revise the AEO results to depict more of a continuing of recent trends in solar PV growth.

The political impasse over environmental regulations in the United States is largely caused by Democrats arguing that stricter regulations are needed to prevent dangerous air pollution and climate change, and Republicans arguing that such regulations are projected to lead to devastating electricity rate increases and job losses. More accurate baseline forecasts could play a role in bridging this divide, because the more solar that is available to replace fossil fuel generation in the near future, the lower are the economic costs of environmental regulations.

References

Carr, Geoffrey. “Sunny Uplands: Alternative Energy Will No Longer be Alternative.” *The Economist*. November 2012.

Lazard. “Levilized Cost of Energy Analysis – Version 5.0.” June 2011.

Riechelstein, S and Yorston M. “The Prospects for Cost Competitive Solar PV Power,” *Energy Policy*, Volume 55, Pages 117–127, April 2013.

U.S. Department of Energy (DOE 2012). “SunShot Vision Study.” February 2012.

U.S. Energy Information Administration (EIA 2008). “Annual Energy Outlook 2008.” June 2008.

U.S. Energy Information Administration (EIA 2009). “An Updated Annual Energy Outlook 2009 Reference Case Reflecting Provisions of the American Recovery and Reinvestment Act and Recent Changes in the Economic Outlook.” April 2009.

U.S. Energy Information Administration (EIA 2010). "Annual Energy Outlook 2010." April 2010.

U.S. Energy Information Administration (EIA 2011). "Annual Energy Outlook 2011." April 2011.

U.S. Energy Information Administration (EIA 2012). "Annual Energy Outlook 2012." June 2012.

U.S. Energy Information Administration (EIA 2013a). "Annual Energy Outlook 2013." April 2013.

U.S. Energy Information Administration (EIA 2013b). "AEO 2014 Early Release." December 2013.