near zero

How Low Will Photovoltaic Prices Go?

AN EXPERT DISCUSSION

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How Low Will Photovoltaic Prices Go?

Summary of a Near Zero Expert Elicitation

Solar power—electricity from photovoltaic panels—is now becoming competitive in certain markets, such as in Germany during the hours of peak demand. But in most other markets, it is still too expensive to compete with older, established sources of power such as coal-fired power plants. In forecasting the future of the solar power industry, and the expansion of clean energy in general, the price of solar power in the next 10 to 15 years will be a crucial factor—perhaps the deciding factor.

To get a sense of what future prices for solar power are likely to be, as well as other challenges and bottlenecks that the industry faces, Near Zero conducted a formal, quantitative survey (an "expert elicitation") that drew on from industry, universities, and national labs. Such surveys are a means of formally collecting expert judgments on a topic. By aggregating forecasts made independently by a variety of experts, the results reflect the collective wisdom of the group about how the solar power industry is most likely to develop, and also help to characterize the range of uncertainty about the future.

The results of Near Zero's survey, conducted in 2011 and 2012, suggest that prices for solar power will continue to fall, in keeping with a long-term trend that has prevailed since 1980. This will bring down the price of solar power sufficiently that it will be far more competitive than it is today. The experts forecast a large expansion of the amount of installed solar power, increasing more than 10 times over the decade from 2010 to 2020, an expansion that will continue at a similar rate until at least 2025.

However, this success story is dependent on solar power prices continuing to fall, which will require continued and possibly increased levels of spending on research and development, the experts said. If solar power prices continue to fall as expected in the survey, then the large expansion of installed solar power could be achieved while requiring spending less each year than the world currently is spending on solar power installations. But if prices were to hold steady rather than falling, then the same expansion of solar power, over the period 2012 to 2025, would cost at least 50% more—adding up to several hundred billion dollars.

Glossary:

Solar module: The part of a solar panel that takes in sunlight and converts it into electricity. In traditional solar systems, it is made of sheets of black silicon. In thin-film solar panels, the modules are made of a thin layer of semiconductor, such as cadmium telluride, that is deposited onto a sheet of metal.

Solar panel: A traditional solar panel includes the module, usually covered with a sheet of glass, and enclosed within a metal frame.

Balance of Systems (BOS): All the parts of solar power system, excluding the solar module. Different solar power systems differ depending on where they're installed (such as on a roof or on the ground), but BOS can include: an inverter (which converts DC electricity from the module into AC electricity for the grid), batteries, charge controllers, and the frame around the module and other support structures.

Annual installations: The amount of solar modules installed, measured by their capacity (the electricity they could produce at the peak time of day, in watts). In 2011, the industry installed about 30 gigawatts (GW, or billions of watts) of solar capacity.

Total installations: The all-time total amount of solar modules installed, up to any given date. Over the roughly 40-year existence of the solar photovoltaic industry, it had installed by the end of 2011, a total of nearly 70 GW of solar modules. Also known as "cumulative installed capacity."

Prices Have Fallen, Most of the Time >

As the solar power industry has grown over the past four decades, prices have plummeted for solar photovoltaic (PV) modules—the part of a solar panel that captures sunlight to create electricity. (See glossary for definitions of solar modules and other components of solar power systems.)

The solar power industry has grown enormously since its early days in the 1970s, and at the same time prices for solar modules have fallen sharply (Fig 1). The total amount of installed solar photovoltaic panels grew from 10 megawatts (MW, or millions of watts) in 1981 to 100 MW in 1987, and then to 1000 MW in 2000.

With each 10-fold increase in the total that had been installed, the average sales price of solar modules decreased by about half—a record that rivals the improvements in other energy technologies. For example, from 1987 to 2000, the total number of solar modules that had been installed increased 10-fold, meanwhile the industry cut module prices by half, from about $8 per watt to about $4 per watt.[1]

From the start of the 2000s, however, it has been more difficult to discern a clear trend in prices. From 2002 to 2007, the industry grew very rapidly, with solar panel installations rising on average 40% each year. During that time, shortages of silicon—the main building block of traditional solar modules—caused the price per watt to actually *increase* during this period, bucking the long-term trend.[2] But since 2007, solar panel manufacturing capacity has expanded greatly while the global economy has struggled—and prices of solar modules have fallen faster than ever before.

Today, prices are roughly back in line with the long-term trend (Fig. 2), and over the long-term, "there is a clear downward trend" in prices, said Gregory Nemet of University of Wisconsin, Madison. However, there are concerns that as a result of high government support, a glut on the market, and resulting competitive price cuts, current prices may be artificially low. According to some analysts, current solar module prices of about $1.10 per watt may not reflect the costs of production, and some manufacturers may be selling at a loss.[3]

Near Zero's Survey >

In the outlook for the coming decade, a few major questions loom. Will the solar industry manage to continue pushing down prices for solar power systems? What would be required, in terms of research funding and industry support? And how much does it matter if this trend continues?

To seek answers to these questions, Near Zero conducted an expert elicitation from 2011 to 2012, posing quantitative questions about future prices of solar power systems, research priorities, as well as qualitative questions about the forces driving the price reductions.

1> The price of modules is expressed here in terms of dollars per watt ($/W) of power output when under full sunlight. 2> Bazilian, M. et al "Reconsidering the Economics of Photovoltaic Power," Bloomberg New Energy Finance (2011), p3. 3> United Nations Environment Programme, "Global Trends in Renewable Energy Investment 2012"; discussion of experts organized by Near Zero.

To assess experts' expectations for the future, Near Zero asked a panel of more than a dozen experts from industry and academia to forecast the future of the industry, answering a series of quantitative and qualitative questions about how quickly the industry might grow, how much the price of solar power systems might change in the future, and what would be required to ensure that solar power continues to get cheaper in the future.

The survey asked experts how long it might take for the solar power industry to reach two milestones, of having produced a total of 300 GW and 600 GW (gigawatts, or billions of watts) of solar modules—roughly 10 times and 20 times more than had been produced up to the end of 2010, respectively. Experts were also asked what the average sales price of solar modules was likely to be at each of those milestones. The questions did not specify policies or economics (such as the level of government support or the price of competing energy technologies); the experts were asked only what they thought was most likely to occur.

Prices to Continue Falling >

The general consensus of these 21 experts—from universities, industry, and government labs—was that, for the next 15 years at least, solar module prices will likely continue to fall, in keeping with the long-term trend since 1980. But for this trend to continue for the long run will require more investment in basic research.

FIGURE 1:

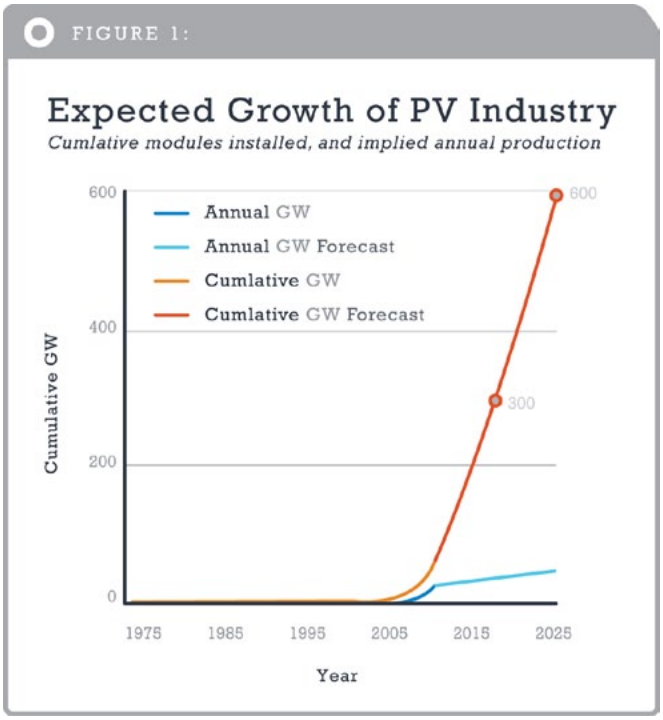

FIGURE 1: **Solar power expected to expand greatly through 2025.** Experts were asked how long they thought it would take to reach cumulative deployment of 300 GW and 600 GW of solar power, and the average answers are marked by red squares.

These expectations fit with an expected rate of growth of annual installations of 4% per year.

On average, the experts estimated that by 2018, the industry will have produced a total of 300 GW of solar modules, and that seven years later, in 2025, the industry would reach an all-time total of 600 GW (Fig. 2). (For comparison, 300 and 600 GW of solar power capacity would supply about 1% or 2%, respectively, of current global electricity use.)

These expected milestones could be met by annual growth of 4% in the amount of modules installed

each year, starting from 2011's record of nearly 30 GW installed. The experts' average expectation is roughly similar to a production forecast from the European Photovoltaic Industry Association (EPIA), for a scenario with moderate support for the PV industry, but forecasts less growth than an EPIA scenario that includes strong market support.[4]

In Near Zero's survey, the PV module prices expected by experts spanned a wide range, but almost all of the experts surveyed expected that prices would continue to drop at least as quickly as the long-term trend. The median price expected after 300 GW of all-time production was $0.77 per watt, and production of 600 GW a price of $0.67—a forecast that prices will drop slightly faster than they have over the long-term, although more slowly than they have in the past few years (Fig. 2).

FIGURE 2:

FIGURE 2: **Falling prices for solar modules. As the total amount of solar modules produced has increased over the past few decades (from left to right), the price per watt has also fallen.** Prices 1975-2009 are from Nemet (2009), and prices for 2010 and 2011 are based on data from Navigant and Bloomberg New Energy Finance.[5] Blue circles indicate the expectations from Near Zero's survey, for solar module prices at 300 GW and 600 GW of total installations (also called cumulative capacity). Also shown for reference in green is the module price target of the Department of Energy's SunShot Program.

4> European Photovoltaic Industry Association, "Global Market Outlook For Photovoltaics Until 2016," May 2012. 5> Nemet, Gregory F. "Interim monitoring of cost dynamics for publicly supported energy technologies," Energy Policy (2009); Ernst & Young "Renewable energy country attractiveness indices," May 2012; National Renewable Energy Laboratory, "PV Manufacturing Cost Analysis,"June 22, 2012.

Breakthroughs Needed >

The past few years have seen large improvements in solar module manufacturing in China that have brought prices down sharply—however, they "have made small if any actual process cost reductions and only at the margins in a 'Southwest Airlines' approach," said Nathan Lewis of Caltech.

Further process cost reductions would require many aspects of the solar power industry to develop favorably, said Gregory Nemet of the University of Wisconsin. These include "reduction in the cost of materials," "technical advances that improve electrical conversion efficiency," and "new technical generations of PV." "If most of these do not occur," he said, "it is hard to see how [the expected prices] can be attained and then sustained."

For prices to fall substantially below the average expectations in Near Zero's survey would likely require changes in the solar power industry, according to comments from many of the participants. For example, experts said that reaching much lower prices would require a "breakthrough in BOTH semiconductor and encapsulation materials costs" (Steven Hegedus, University of Delaware), or a "breakthrough in installation methodology" (Danielle Merfeld, GE Global Research).

These responses stress the need for continued research and development in order for prices to continue falling for the long term, beyond the next decade.

Billions of Dollars at Stake >

Although the differences in prices per watt may seem small between current PV module price per watts and what experts expect in coming years may seem small, the experts also expect hundreds of billions of watts of solar panels to be installed—so even small differences in prices quickly add up.

Annual growth in annual installations would need to be approximately 4% to fit with the experts' average expectation for reaching 300 GW and 600 GW by 2018 and 2025, respectively. If prices for solar modules and BOS also fall as expected by the surveyed experts, then annual expenditures on solar photovoltaic energy could gradually decrease from the record spending in 2011 of $147 billion, even as the total amount of installed solar systems increased each year. Therefore, anticipated price reductions would allow an increase in annual installations matching the experts' expectations, without requiring that the world spend more on installations each year than it did in 2011.

However, for prices to continue to fall for the longer term will require continued investment in R&D, the experts said. And to exceed these expectations, by installing more solar power than the experts forecast, could require an increase in the annual expenditures on solar power.

For comparison, if solar power prices were to hold steady, then the same expansion of solar power would cost far more. The total expenditures required

through 2018, for example, would be roughly 50% higher, adding up to several hundred billion of dollars.

Near Zero's survey showed some difference in the outlook among experts. Those from universities were somewhat less optimistic, expecting that prices would fall but not as fast as the long-term trend, while those with industry experience expected prices to continue along the path they have followed since the early 1980s.

In comparison, the U.S. Department of Energy's SunShot Program—which, from 2011 to 2016, will spend $112 million on research and development of "advanced solar photovoltaic-related manufacturing processes"—has a goal of bringing solar module prices down to $1 per watt by 2016 and to $0.50 per watt by 2020. These goals imply reductions in price that are somewhat more optimistic than both the results of Near Zero's expert elicitation and the long-term trend since 1980 (Fig. 2).

SunShot has also set a goal for reducing the price of entire solar power systems, which include many other expenses besides solar modules, including steel frames, labor expenses for installation, and more. (As described in the glossary, these other parts of a solar system are known as "balance of systems," or BOS.) SunShot's goal is to get the price for whole systems down to $2.20 per watt by 2016, and $1 per watt by 2020. Near Zero's survey suggests these goals are quite ambitious, but may be possible to reach, with the chance of success around 50%.

The New Dominance of "Balance of System" >

Even if solar module prices continue to fall, there will still need to be a concerted effort to ensure that the other parts of a solar power system—the "balance of systems," or BOS—also continue to get cheaper as well. The expenses for BOS can include metal frames, concrete pads, labor for installation, and inverters that convert the solar panels' DC electricity into AC electricity suitable for appliances or transmission through the electric grid. The Intergovernmental Panel on Climate Change has documented that solar system prices have fallen over the past several years, showing that both modules and BOS have become cheaper as the industry has grown.[6]

In Near Zero's survey, the experts expected prices for BOS would be able to fall at least as rapidly as prices for modules. They estimated that when the industry reaches 300 GW of all-time production, BOS would make up 55% of the price of a solar power system. Before the rapid price drop of 2010 and 2011, BOS accounted for about 45 to 50% of the price of a solar system.[7] However, with prices for modules dropping rapidly in recent years, now BOS makes up about 60 to 65% of the price of a solar system.[8] The results of Near Zero's survey suggests that BOS prices are likely to continue to fall at roughly the same pace as solar module prices, with both contributing to making solar systems cheaper.

The situation today, with BOS expenses making up more than half the price of a whole solar sys-

6> Intergovernmental Panel on Climate Change, "Special Report on Renewable Energy Sources and Climate Change Mitigation" (2012). 7> Bony, L. et al, "Achieving Low-Cost Solar PV," Rocky Mountain Institute (2010). 8> Solarbuzz, "Retail Price Summary - March 2012 Update" at *http://www.solarbuzz.com/facts-and-figures/retail-price-environment/module-prices*

tem, is a historic reversal from the situation that had prevailed through the whole history of the solar industry. According to Near Zero's survey, even though BOS prices will likely drop over the coming decade, nonetheless they will continue to make up more than half the price of a whole solar system.

Because of this new dominance of BOS expenses, most experts believe research and development should focus increasingly on ways of bringing down BOS prices, Near Zero's elicitation found. Yet most experts supported the SunShot Project's emphasis on research on new photovoltaic materials. This work could lead to more efficient solar modules, able to harness a greater share of the sunlight hitting them and produce more watts per square foot. In this way, more efficient modules would indirectly reduce the outlay for BOS, according to Near Zero's elicitation.

More efficient modules would indirectly reduce the outlay for BOS, according to Near Zero's elicitation. "Improving efficiency is a very important driver to reduce balance of system [prices]," explained Doug Rose, Vice President of Technology Strategy at SunPower Corp.

Nathan Lewis of Caltech added, "lower efficiency means more area needs to be covered with support structures to produce the same power output"—and that translates into higher spending on steel, labor, and other requirements. On the other hand, research that boosts the efficiency of solar panels would lower the expense of BOS. Watt for watt, more efficient panels mean smaller panels—and that means less expense for BOS. "Efficiency is at a premium," Lewis added.

Research can also help bring down BOS prices directly—and research into BOS should be the next-highest priority after photovoltaic-active materials, most of the experts agreed. SunShot likewise places a heavy emphasis on reducing BOS prices, with a goal of seeing prices for solar panels and BOS fall equally fast, each dropping about three-quarters by 2020. If BOS prices remained at today's rate—more than $1.50 per watt—then it would be impossible to meet SunShot's goal for a price on entire solar systems of only $1 per watt.

Near Zero's results suggest that SunShot's goal is fairly ambitious, but achievable. The project's goals involve cutting the price of both solar module and BOS at about the same rate, a cut of about three-quarters from 2010 to 2020. Over the past 20 years, it appears BOS prices have not fallen as fast as solar module prices. But Near Zero's results show that experts expect BOS prices to fall rapidly in the next decade, perhaps as quickly as prices for solar modules.

However, a complicating factor is that BOS prices are highly regional, depending on factors such as local labor costs, and the experience and efficiency of the local solar installation industry. As Doug Rose of SunPower Corporation said, "much of the progress in costs [in a region] must come from the build-up of infrastructure and knowledge (of installers, utilities, permitting bodies, and customers) from installation in that region." Such progress in Germany, for example, has brought down the price of whole solar systems, but not all countries have had this success.

For these reasons, the experts agreed that to make solar power cheaper, a major priority should be efforts to bring down BOS prices. One approach is to improve modules' efficiency, so that they take up less space—and so require less materials and labor for the rest of the system. But there are other, equally important ways of reducing the BOS prices, according to Near Zero's elicitation. When asked to rank the best options for reducing BOS prices, the experts agreed that two additional means of reducing BOS prices would be especially effective:

- Work on standardizing the installation of solar PV systems, to make installations faster, requiring less labor and customization.
- Removing administrative barriers, including paperwork required for installation permits.

Misleading Metrics >

The results of Near Zero's survey also suggest that benchmarks that leave out the BOS prices are misleading—increasingly so in recent years.

In studies of the solar industry—including by the Department of Energy, the European Photovoltaic Industry Association, and the IPCC—it has been common to display a "learning curve," showing how solar module prices have dropped as the industry has grown over the past four decades. Likewise, often the learning curve mixes together both traditional solar panels and newer thin-film panels (as in Fig 1 in this summary), or the graphs show two learning curves side-by-side for each of the two solar module technologies.

But since such a curve only shows module prices, it ignores BOS prices. This, in turn, could give the impression that solar system prices are dropping faster than they are, or that thin-film technologies are more competitive than they actually are.

According to Near Zero's elicitation, a better way of capturing the progress in the solar industry would be to focus on price per watt for whole solar systems, or the levelized price of electricity produced by solar systems—both metrics that factor in the BOS prices.

Table 1

Level of Participation Key

- Participated in the Discussion
- Participated in Elicitation 1
- Participated in Elicitation 2

TABLE 1. List of experts who participated in the Near Zero survey. A total of 21 experts participated in this elicitation. Seven were a part of a discussion in summer 2011, and 16 participated in a quantitative elicitation in 2011. In a follow-up elicitation in 2012, 13 experts participated.

- Jay Apt *Carnegie Mellon University*
- Martin Green *University of New South Wales*
- Steven Hamburg *Environmental Defense Fund*
- Steven Hegedus *University of Delaware*
- Max Henrion *Lumina Decision Systems*
- Martin Hoffert *New York University*
- David Keith *Harvard University*
- Page Kyle *Pacific Northwest National Laboratory*
- Nate Lewis *California Institute of Technology*
- Robert Margolis *National Renewable Energy Laboratory*
- Paul Maycock *PV Energy Systems, Inc*
- Danielle Merfeld *GE Global Research*
- Juan Moreno-Cruz *Georgia Institute of Technology*
- Gregory Nemet *University of Wisconsin, Madison*
- Bruce Parkinson *University of Wyoming*
- Doug Rose *SunPower Corporation*
- Sean Shaheen *University of Denver*
- Daniel Tarico *Viasol Energy*
- Thomas Utrup *Solar Power Industries*
- David G. Victor *University of California, San Diego*
- Ryan Wiser *Lawrence Berkeley National Laboratory*

Appendix 1.

List of questions asked, and detailed responses:

Questions on solar module prices >

In the initial elicitation, in which 16 experts replied, experts were asked a series of questions about their expectations for solar module prices in the future:

- What is the ***lowest*** average price[9] you can imagine for solar PV modules at 300 GW [gigawatts] of cumulative deployment?
- What is the ***greatest*** average price you can imagine for solar PV modules at 300 GW of cumulative deployment?
- What is the probability that the average price for solar PV modules at 300 GW of cumulative deployment will be ***less than X***? [X, and below Y and Z, were intermediate prices between the lowest and greatest prices that each expert gave in reply to questions #1 and #2.]
- What is the probability that the average price for solar PV modules at 300 GW of cumulative deployment will be ***less than Y***?
- What is the probability that the average price for solar PV modules at 300 GW of cumulative deployment will be less ***than Z***?

In the second elicitation in summer 2012, Near Zero asked the same questions, but for prices at 600 GW of cumulative deployment, and 13 experts replied.

FIGURE A1:

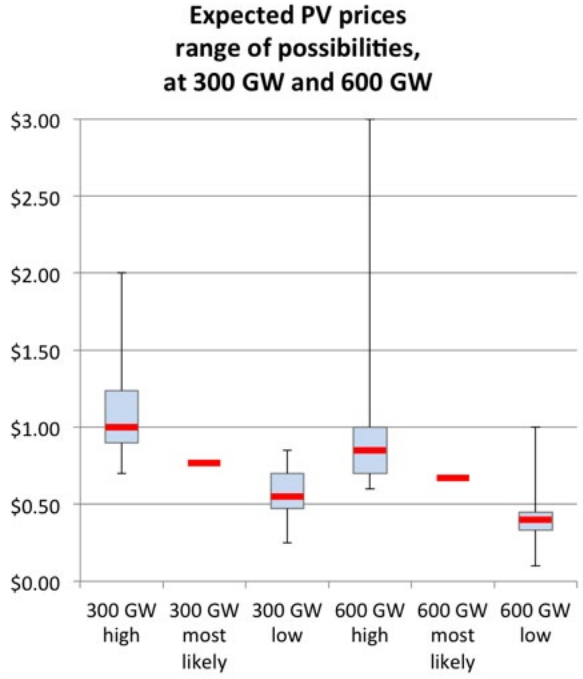

FIGURE A1: **Expected prices for solar PV modules, at the points when the world has reached 300 GW or 600 GW of cumulative deployment.** Experts were asked to give a range of answers, to reflect their uncertainty about what prices may be in the future.

Given the experts' answers to all five questions, the most likely expected price at 300 GW was $0.77/W, and at 600 GW was $0.67/W. In the graph, the median answer for each question is indicated by the red bar the solid box represents the middle 50% of experts' answers, and the outer bars represent the maximum and minimum answers received for each question. The most likely prices were computed using the experts' answers to all of the questions above.

9> By "average price" we intend the mean sale price of PV modules to the project developer or end user at the point in time when the specified cumulative (global) capacity threshold is achieved irrespective of specific technology. We ask price and not cost because price data is more available and ties these questions back to the Note by Keith and Moreno-Cruz. Price requested is for modules only, excluding balance of system price. Price expressed in dollars per watt-peak ($/$W_p$)

The two elicitations had partially overlapping sets of experts (16 experts in the first round, 13 experts in the second round, with 8 who participated in both). The results for all experts are shown in Figure A1; the results for each round are not significantly different when limited to just the 8 experts who participated in both rounds.

Experts were also asked about their expectation for the "learning rate"—that is, the rate at which solar module prices will fall, as the total amount produced increases over time. Over the past few decades, the price has fallen at roughly a 20% learning rate, which means that each time the cumulative production doubles (say, from 10 GW to 20 GW), then the price falls by 20%.

- Question: What do you think the learning rate of solar PV modules will be between the present and 300 GW cumulative deployment? (Answers expressed learning rate as a percentage.)

FIGURE A2:

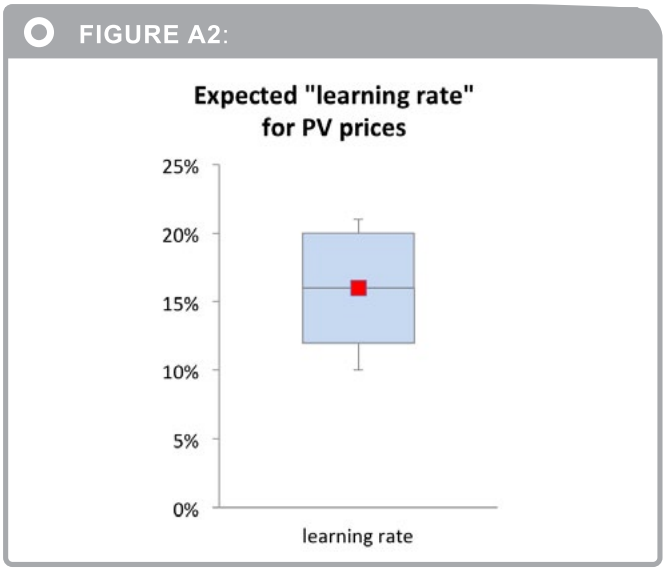

FIGURE A2: The median expectation for the learning rate was 16% (marked by the red box), somewhat lower than the learning rate has been historically. The colored box represents the middle 50% of experts, and the outer bars represent the highest and lowest answers to this question.

The answers to this question were somewhat lower than the implied learn ing rate, given the experts' expectations for solar module prices (see Fig 2 in the main text), which was consistent with a learning rate of 20% or higher.

Questions on balance-of-systems (BOS):

- At 300 GW cumulative deployed capacity, what fraction of the total turnkey cost[10] of a new 100 MW PV installation (i.e. utility scale) do you think will be non-module costs? (answers range from 0.0 to 1.0)

10> By this we mean all costs and expenditures that must be covered before a product is ready to be sold and used, including direct costs, like materials, also indirect costs including administrative expenses and product engineering.

FIGURE A3:

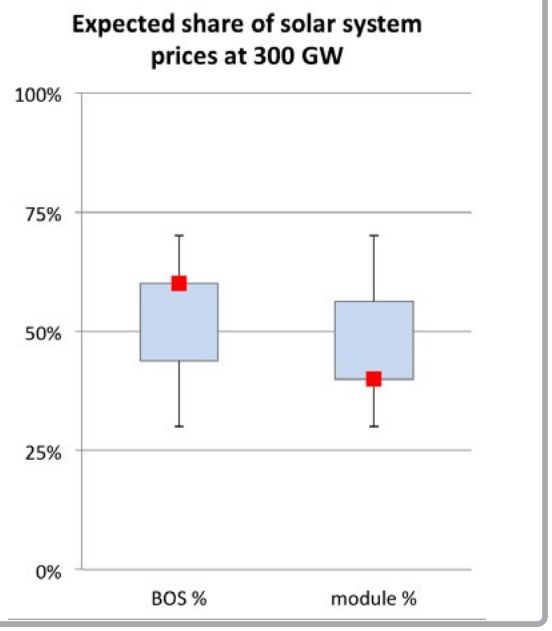

FIGURE A3: **Experts expected that BOS would make up a similar amount of total system cost in the future as it does today.**

Please rank the following means of reducing total balance-of-systems costs of utility-scale PV installations. (rank from highest priority to lowest priority) Choices:

- increase module efficiency
- improve electronics
- improve structural components
- create training programs for installers and servicers
- standardize installation practices and hardware
- remove administrative barriers
- simplify grid-connections
- net-metering

FIGURE A4:

	number of votes for each ranking						
highest priority	#1	#2	#3	#4	#5	#6	#7
Standarize Installation	3	3	1	4	1	1	0
Remove Administrative Barriers	3	4	1	2	0	2	1
Increase Module Efficiency	4	3	1	0	3	0	2
Improve Electronics	2	2	4	1	2	1	1
Simplify Grid Connections	1	3	1	3	1	2	2
Improve Structural Components	0	1	3	1	4	2	2
Create Training Programs	0	0	3	2	2	3	3
lowest priority							

FIGURE A4: **To reduce BOS prices, experts said the most important issues are: standardizing installation, removing administrative barriers, and increasing module efficiency.**

Questions on budget allocations:

- How would you allocate the DOE SunShot budget to minimize the installed cost of solar PV in 2020? (The budget was shown divided into five categories—PV active materials, Area-related BOS, Power-related BOS, Manufacturing, and Human Experience—each of which was subdivided into smaller categories. The experts were able to click and drag on boxes representing the budget for each category, to show how they would choose to allocate the budget.)

FIGURE A5:

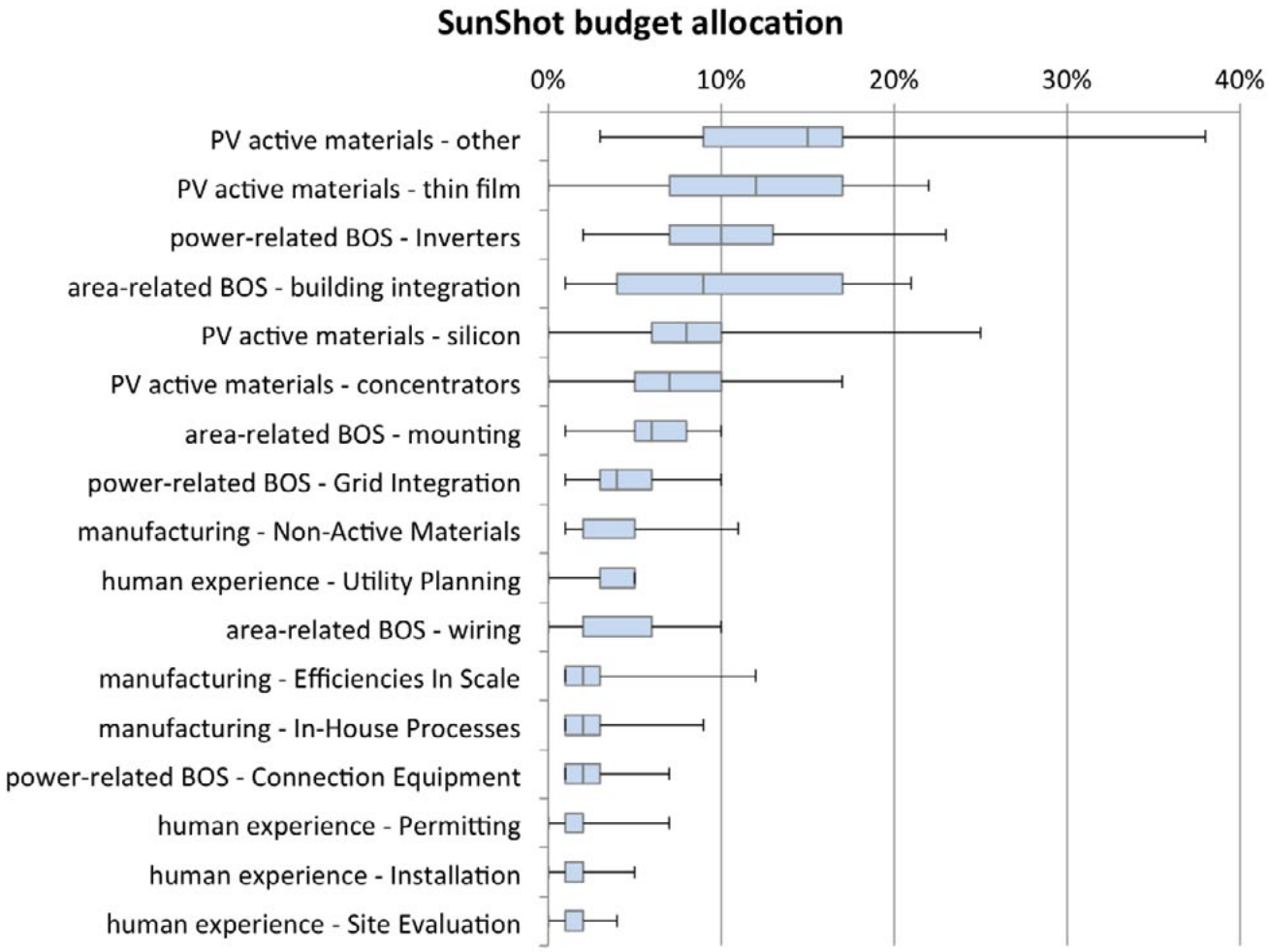

FIGURE A5: **Experts ranked PV active materials as the highest priority for research funding, in particular funding for materials other than silicon. Also highly ranked were efforts to reduce BOS prices, including inverters and efforts toward integrating solar systems with buildings.**

- The government puts you in charge of a $100m fund. Your sole goal is to minimize the installed cost of PV by 2020. Where do you spend it? (The experts chose the fraction that goes to RD&D—research, development, and deployment—with the remainder going to deployment incentives.)

FIGURE A6:

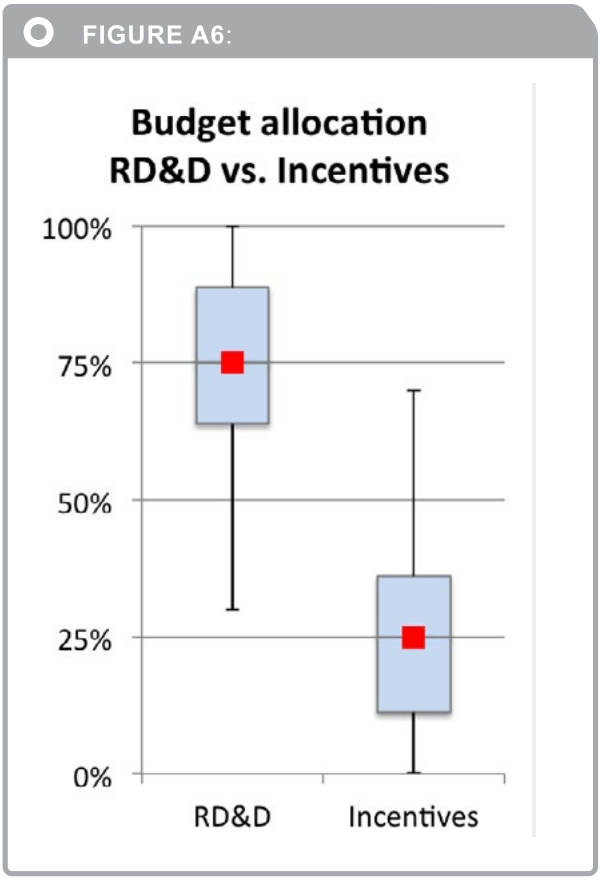

FIGURE A6: **In order to reduce the cost of solar power by 2020, experts chose to put most of a hypothetical $100 million fund toward RD&D as opposed to deployment incentives.**

- How would you allocate government RD&D funding to minimize the installed cost of solar PV in 2020? (The budget was divided into three types of funding: basic, applied, and manufacturing. Each of these in turn was divided into three types: academic, national labs, and industry, giving a total of nine categories for which the experts could adjust the budget.)

FIGURE A7:

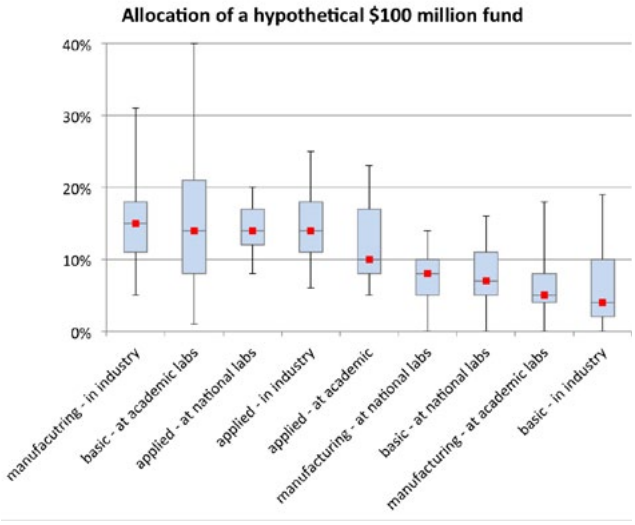

FIGURE A7: **Experts divided a hypothetical $100 million fund into each of 9 categories. The preference was for industry to receive more of the funding for manufacturing work, academic labs to receive more of the funding for basic research, and for national labs and industry to share in applied research.**

- The DOE's SunShot Program aims to reduce PV system prices to $1.00 per watt by 2020, which assumes $0.40 per watt for the module and $0.60 per watt BOS. How likely is it that the module price target of $0.40 watt will be achieved? (probability between 0.0 and 1.0) How likely is it that the balance-of-systems price target of $0.60 per watt will be achieved? (From 0% likelihood to 100% likelihood)[11]

11> This is how the question was asked in the survey, but the numbers were not correct. The actual SunShot targets are $0.50 per watt for modules and $0.50 per watt for BOS. Nonetheless, the experts' answers indicated that targets in this range would possible, albeit difficult to achieve.

FIGURE A8:

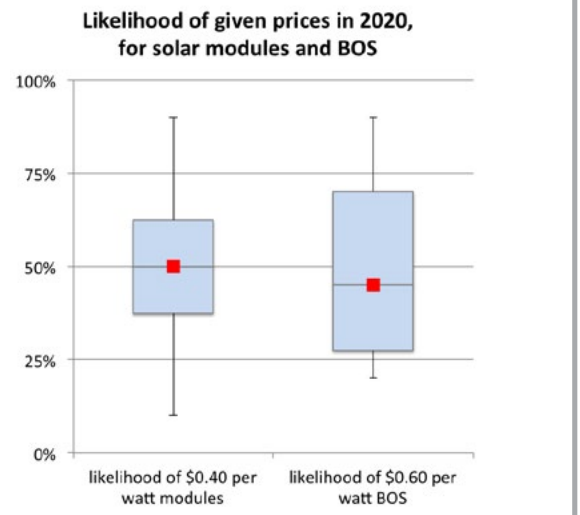

FIGURE A8: Experts were asked how likely specific prices would be in 2020.

Question on expected growth of installed solar systems:

- In what year do you anticipate 300 GW of solar PV capacity will have been deployed?

FIGURE A9:

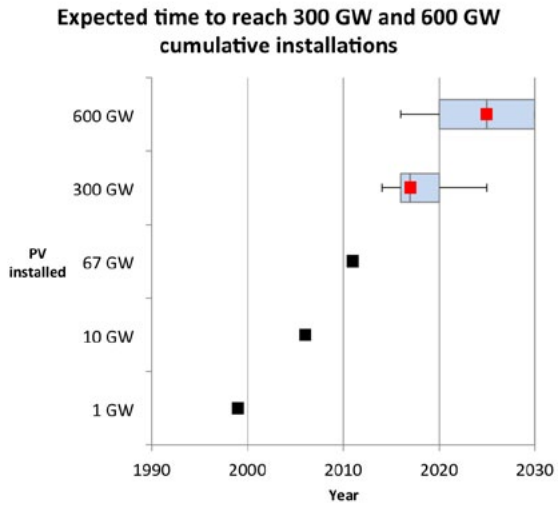

FIGURE A9: Experts forecast, on average, that it would take until 2018 to reach 300 GW of cumulative solar deployment, and until 2025 to reach 600 GW.

The colored box represents the middle 50% of answers to each question, and the outer bars represent the highest and lowest answers.

Experts were asked to agree or disagree with several statements. They were asked: "Review each statement and indicate whether you generally agree or disagree with it.":

- The very rapid drop in [module] prices from 2008 to 2011 is unlikely to continue.

  Response: **12 of 13 experts agreed.**

- Current levels of spending on solar PV R&D are sufficient to maintain a module learning rate of 19% over the next two doublings of PV capacity (i.e., to ~300 GW)?

  Response: **5 of 13 experts agreed.**

- Reducing BOS costs should be the top priority in making PV electricity more economically competitive.

  Response: **8 of 13 experts agreed.**

- Global BOS costs have not decreased much in the past two decades.

  Response: **4 of 13 experts agreed.**