



fab2farm™



**New Model Creates Jobs,
Delivers Lowest Solar Energy Cost**

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ABSTRACT

To deliver cost-effective, utility-scale solar energy, the solar industry must address the issue of cost. There are three main contributors to total installation cost: module prices, balance-of-system costs, and financing costs. The Applied Materials SunFab™ manufacturing line supports a complete economic infrastructure and is designed to achieve the lowest installed solar energy cost. A SunFab manufacturing facility can also become a regional job creation engine, potentially generating more than 2,500 high-skilled jobs in panel manufacturing and installation, and more than \$400 million in economic activity every year – creating an Applied Materials fab2farm™ ecosystem.

INTRODUCTION

Cost is the single most crucial obstacle facing most renewable energy technologies. In order to have a meaningful impact on the overall energy economy, renewable energy must be affordable. To become more affordable, renewable technologies must achieve production volumes large enough to exploit economies of scale.

The issue of affordability is especially acute for solar-generated electricity. Though solar generation is suitable for on-grid and off-grid installations such as urban rooftops and open space locations – making it in fact more flexible than other renewable technologies – it is often seen as a boutique technology, too costly for mainstream power generation. The reality however is that the cost of typical solar photovoltaic (PV) modules has fallen from nearly US\$19 per Wp (watts at peak output) in 1982¹ to around US\$4.50 per Wp today². When installed cost falls below US\$4 per Wp³, solar begins to be cost-competitive with fossil-fuel based and other grid power for peak electricity generation. The price declines to date have helped stimulate respectable growth in the solar sector. Between 1997 and 2007, the industry achieved a compound annual growth rate of 39% per year⁴. Even at a more sustainable 29% compound annual growth rate by 2020 there will be 250 gigawatts (GW) at peak output of installed solar PV capacity worldwide⁵. Solar PV has progressed technologically to a point where it is conceivable to see it become a significant part of the world's energy mix. Yet actually achieving this vision requires more than just technological advances. After all, to be able to scale from kilowatt (KW)-sized installations on residential rooftops to thousands of megawatt (MW)-scale solar farms, the industry also needs business model innovations that meaningfully drive down costs.

Most discussions of solar energy cost focus on the price of modules alone, which is only one part of the cost equation. In fact, balance-of-system (BOS) costs (including installation) and financing costs play a pivotal role in the overall solar energy cost. This paper demonstrates a new integrated strategy that can favorably impact all major cost components with the ultimate goal of making solar a meaningful contributor to the world's energy supply while positively impacting economic growth and job creation.

REDUCING MODULE COST

Though modules are not the only factor in solar installation costs, they are certainly important and have attracted years of attention from solar industry researchers. However, some solar cells carry structural costs that are beyond the control of any single manufacturer. For example, conventional crystalline silicon (c-Si) solar cells start with a high purity silicon ingot for which the price of the raw material has been extremely volatile. Further, because there are few turnkey c-Si suppliers, each processing and assembly step is usually performed by a different vendor, making it harder to manage the supply chain and control costs. C-Si cells do offer higher efficiencies, which have made it the technology of choice for smaller installations.

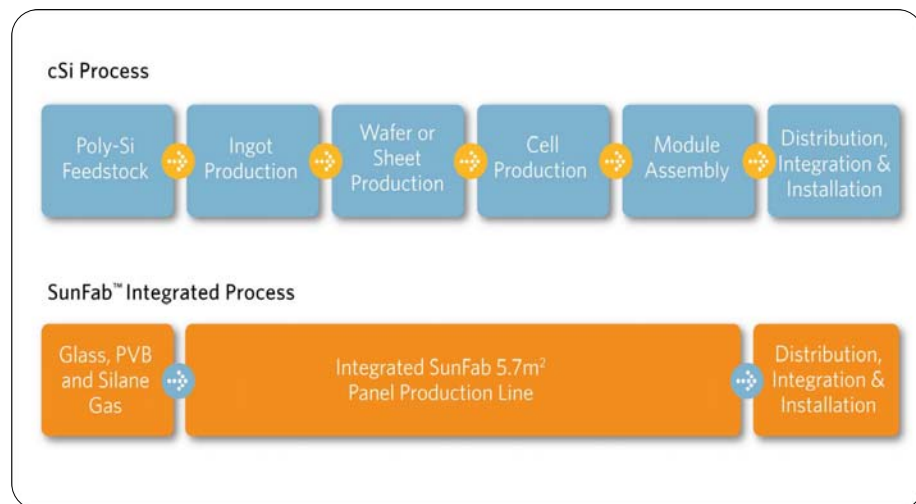


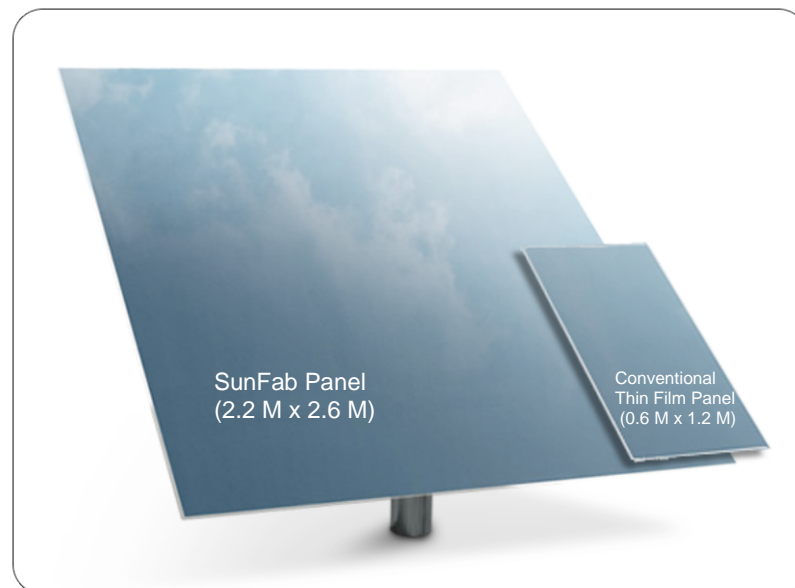
Figure: c-Si processing vs. SunFab thin film processing

In contrast, choosing a turnkey solution like Applied Materials' SunFab manufacturing line for thin film amorphous silicon (a-Si) solar cells consolidates module manufacturing within a single factory. Commodity components such as glass, Polyvinyl Butyral (PVB) and silane gas enter the beginning of the line, and finished modules emerge from the end. Because a thin layer of high purity silicon, deposited from silane gas, replaces the thick silicon wafers in conventional c-Si panels, thin film panels consume far less silicon and therefore have lower material costs. With most of the module manufacturing process under one roof, the module cost structure is easier to analyze and predict. Module manufacturers can seek out the most cost-effective suppliers directly, and can

hold a single equipment vendor responsible for cost and performance targets. For utilities and other customers, the consolidated manufacturing process simplifies accountability for any difficulties, rather than spreading responsibility across the supply chain.

Based on mature and scalable silicon deposition technology, the SunFab thin film line™ leverages Applied Materials' four decades of experience in silicon-based manufacturing. Looking back, technical innovations in integrated circuit manufacturing contributed to a 20 million-fold reduction in transistor cost over the last thirty years, helping to create the information age. In flat panel liquid crystal display manufacturing, a 20x cost reduction in thirteen years has been achieved, putting flat screen monitors in homes and offices throughout the world. And in solar module manufacturing, the same can happen. Applied Materials expects that optimization of its solar panel processing technology along with continuous advances of manufacturing efficiency will drive costs below \$3.50 per installed watt by 2010.

LARGER MODULES DRIVE DOWN BALANCE-OF-SYSTEM COSTS



The advantages of the SunFab model go beyond the module technology. Full-size SunFab panels are 5.7 square meters, or eight times larger than

conventional 0.72 square meter panels. In thin film deposition processes like those used in the flat panel display and solar industries, many incremental costs depend on the number of panels passing through the line, not the size of the panel. Larger 5.7 panels thus cost less per unit of area and can drive module production costs below \$1/Wp by 2010.

Still more savings accrue when BOS costs are considered. Costs such as cabling, junction boxes, support brackets, and installation labor all depend on the number of panels installed. For example, a 20 MW solar farm would require just 35,000 full-size 5.7 panels, compared to approximately 230,000 conventional size panels. Another advantage is that if necessary, the large panels can be cut to whatever dimensions, giving the most efficient coverage at a given site.

Though larger panels reduce BOS costs, additional efficiencies can be achieved by rethinking the business model for solar installations. Currently, most large solar projects are unique — designed from scratch with whatever modules, wiring, mounting hardware, and other components are available. True utility-scale solar energy would be able to minimize BOS costs by planning component purchases for megawatts of capacity at a time.

THE ROLE OF FINANCING AND TAX CONSIDERATIONS IN ACHIEVING THE LOWEST OVERALL COST

Until now, most utility-scale solar projects have been built under power purchase agreements (PPAs). Under a PPA, a utility agrees to buy electricity from an independent site developer, who bears virtually all of the risks associated with the project. The developer typically must acquire the land, buy the solar panels, buy and install all necessary wiring, and arrange interconnection to the grid before it can begin to realize any revenue under the PPA. As part of shouldering these risks, the developer owns the solar farm and also benefits from any available tax credits associated with it, such as the federal investment tax credit (ITC). Depending on the facility's tax environment, the developer may or may not be in a position to exploit these credits.

The nature of PPAs makes reliable execution inherently difficult for developers. To win a PPA contract with a utility, site developers generally must offer their electricity at the lowest possible price. Meanwhile, the cost of such installations

may be impacted by financing challenges and also is prone to unpredictable increases for reasons that may be outside the developer's control.

In many cases the site developer, often relying on venture funding, is focused on a handful of relatively small projects, with little or no expectation of revenue until those projects are completed and connected to the grid. Without a steady revenue stream, developers may not be able to attract reasonably-priced financing for longer term multi-megawatt projects. Because their future project plans are uncertain, they may have difficulty obtaining favorable forward pricing for either solar modules or other balance of system components. Delays in grid connection can impose severe additional costs on developers who may already be in precarious financial situations.

The trend to PPAs was due in part to regulations that prohibited utilities from using renewable energy investment tax credits (ITC). Therefore, utilities did not have this incentive to directly own solar facilities. And ITCs usually expired after a year or two, with eligibility requirements shifting with the political winds, dampening developers' desire to undertake larger projects.

In October 2008, however, two important changes reshaped the landscape for utility-scale solar energy. The federal Emergency Economic Stabilization Act (EESA) extended the 30% renewable energy ITC for eight years⁶, enabling better visibility and predictability – two fundamental requirements for long term planning. Significantly, the EESA also lifted the prohibition against utilities' use of the ITC. As a result, while PPAs may still provide a favorable financial structure, alternative approaches have become more feasible than ever before.

In one of these alternatives, a manufacturer of solar modules would enter into an off-take agreement with a utility – under which the utility agrees to buy a certain number of modules (measured in megawatts of generating capacity) over the course of five years or more – which are installed on a solar farm owned by the utility. Under this structure, the module maker may be able to obtain favorable financing for plant construction, and can standardize cabling, electrical inverters, mounting hardware, and other module components. Similarly, with a predictable supply of modules from a single source, the utility is able to plan its investments in land and transmission capacity, placing solar generation near current or anticipated demand centers. High volumes allow both the utility and the module

manufacturer to lock in favorable forward component pricing to achieve the lowest cost per installed watt.

The impact of efficient financing on the cost of a solar installation can be substantial. For example, with a five-year off-take agreement, covering 400MWp of solar modules, the installed price could approach \$3/Wp. Once installed, the modules can be expected to produce approximately 500 GW hours of energy annually (assuming 1,750 hours of sunshine, typical for the south-central US), at an annualized cost of about US\$65 million over their 25-year operating life. A comparable natural gas-fired peak generation plant would incur between US\$33 and \$56 million in annual fuel costs. Thus, the net ratepayer impact for a typical 10 TWh operator could be as low as \$0.001 per KWh⁷.

FAB2FARM BUSINESS MODEL DRIVES REGIONAL JOB CREATION

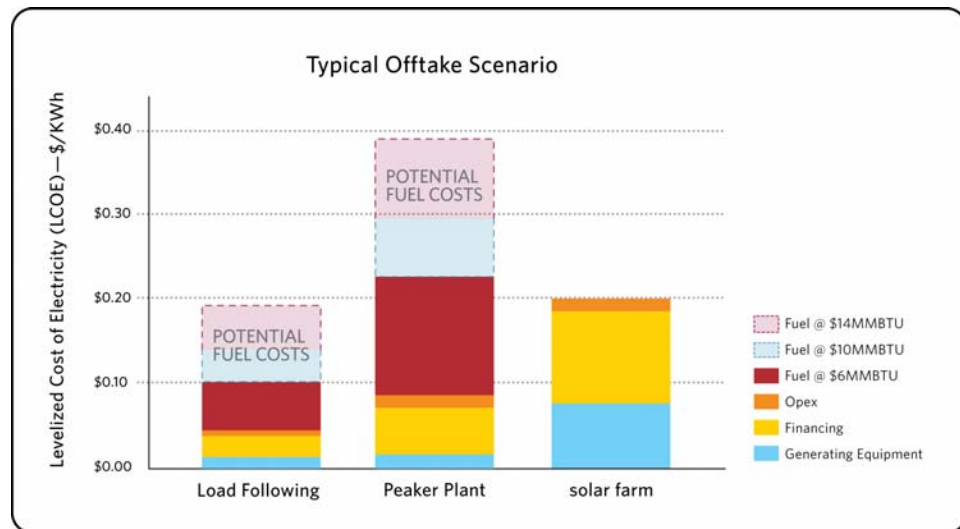


Figure: Typical financial scenarios for a solar farm vs. a gas-fired peaker plant

Local siting facilitates a close relationship between the module manufacturer and the utility, increasing trust and simplifying resolution of any problems that may arise. More broadly, the combination of local module manufacturing and local solar installations can create a regional economic engine, generating a steady supply of skilled jobs. A study by the Renewable and Appropriate Energy Laboratory (RAEL) at UC Berkeley found that adoption of renewable energy technologies leads to net job creation, even after jobs lost in fossil fuel industries

are considered. Most jobs associated with fossil fuel-generated electricity are connected to fuel extraction and processing. Yet these jobs are being displaced by increased use of automation: fossil fuel industry employment declined 66% between 1980 and 1999⁸. Solar energy, in contrast, requires no fuel and little maintenance. Instead, most jobs generated are in module manufacturing — including manufacturing of the commodity materials supplied to the plant — and in panel installation. Both these areas require electricians, equipment technicians, and manufacturing and design engineers.

The macroeconomic impact of pro-renewable energy policies is difficult to evaluate, the RAEL study explains, due to the uneven distribution of energy resources and the interaction of factors in a complex economy⁹. The impact of a local commitment to solar energy is much more dramatic and easier to calculate. While initially, a manufacturing facility might dedicate its output to a single utility under an off-take agreement, the combination of manufacturing and installation expertise is able to serve demand from neighboring municipal utilities as well. As solar energy demand grows, the region's infrastructure can grow with it. A single 80MW SunFab manufacturing line directly employs about 150 full time workers, while solar farm installation creates about 10 jobs per megawatt installed¹⁰. Facility construction, module components, and balance of system components all generate additional indirect employment. Over six years, Applied estimates that a single SunFab line directly or indirectly could generate more than 2,500 jobs and account for more than US\$2 billion in economic activity.

As this discussion shows, the fab2farm ecosystem based on SunFab manufacturing addresses module cost, balance-of-system cost, and financing cost, the three critical components of overall solar installation cost. By minimizing all three, utilities and their customers get carbon-free renewable energy and high-skill jobs, with minimal impact on electricity rates.

KEY TERMS

PVB = polyvinyl butyral
BOS = balance of system

PPA = power purchase agreement
ITC = investment tax credit

REFERENCE

¹ P. Mints, Principal Analyst, Navigant Consulting PV Services Program, private communication, 2008

² SolarBuzz Module Price Index, <http://www.solarbuzz.com/ModulePrices.htm>

³ Applied Materials estimate.

⁴ Paula Mints, “Thin Film Technologies Many New Entrants and What about Crystalline?” presentation at Thin Film Solar Summit, San Francisco, Dec. 2-3, 2008.

⁵ Based on EPIA estimate of 9 GW cumulative installations in 2007. “Global Market Outlook for Photovoltaics until 2012,” http://www.epia.org/fileadmin/EPIA_docs/publications/epia/EPIA__MarketPublication_18feb.pdf

⁶ More details on this credit can be found at http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F&re=1&ee=1

⁷ Applied Materials data

⁸ Kammen Study, Renewable and Appropriate Energy Laboratory (RAEL), UC Berkeley, 2004
<http://rael.berkeley.edu/files/2004/Kammen-Renewable-Jobs-2004.pdf>

⁹ Kammen Study, Renewable and Appropriate Energy Laboratory (RAEL), UC Berkeley, 2004
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¹⁰ Applied Materials data



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A vertical, abstract graphic element on the right side of the contact box, consisting of several overlapping, curved yellow and orange shapes that resemble a flame or a stylized letter 'A'.

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