From Arco Solar to the gigawatt age: past, present, and future of photovoltaic manufacturing reside in SolarWorld USA's facilities

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ABSTRACT

SolarWorld USA's two main manufacturing facilities in Camarillo, CA, and Hillsboro, OR, represent the past, present, and future of crystalline-silicon solar photovoltaic manufacturing in the United States. The Southern California site, which sits in a small industrial park across from a verdant expanse of strawberry fields, was home to one of the world's first (and at one time the largest) solar factories in the late 1970s, a historic campus that has changed corporate hands several times, from Arco Solar to Siemens Solar (1990) to Shell Solar (2001) and finally to SolarWorld (2006) over the three decades since its inception. This article provides a look inside the factory doors.

The Arco epoch was an especially noteworthy one in the early go-go days of the industry. The firm, a division of petrochemical giant Arco and led by PV pioneer Bill Yerkes, became the world's number-one solar company. It was the first to make more than 1MW of modules in a year, the first to commission a 1MW grid-tied power plant, the first to get UL listings for solar panels, and the first to offer UL-listed junction boxes. A gallery of heritage modules in a lobby at Camarillo bears witness to the unique legacy of the production site – from the skinny, two-cell-wide 15-, 20-, and 30-watt antiques through the increasingly sophisticated Siemens and Shell models to the high-power 72-cell units produced at the plant today.

This was once a place where just about every step in the photovoltaic production value chain was done (and in some cases invented) – from pulling ingots to making wafers to designing and building process equipment to conducting R&D to manufacturing cells and panels. Although the Camarillo factory now pumps out SolarWorld's monocrystalline-silicon modules mostly for the North American market on a new automated 100MW capacity line, the site has been a hotbed of thin-film PV development at various times, including a multimegawatt copper-indium-selenide (CIS) pilot line during the Siemens and Shell eras (technology that lives on in the Avancis venture in Germany).

The Oregon location, set on 97 acres not far from the fabled Intel digs in the suburbs of Portland, was once a Komatsu Semiconductor silicon ingot and wafer-making plant that, due to one of the inevitable down-cycles in the semiconductor business, lay idle and was never fully equipped, let alone ramped up to production. SolarWorld bought it in 2007 and has since poured hundreds of millions of dollars into tearing out floors and ceilings, knocking down walls, and otherwise retrofitting the facility.

The company is finishing a new 210,000 sq ft logistics and production building, which will turn the site into a vertically integrated, 21st century solar PV fab complex that will reach a nameplate

Photo: SolarWorld

Solar cells run through a highly integrated, closely monitored process flow.

capacity of 500MW by 2011 – the largest of its kind in North America. There's enough land on the Oregon site to build another factory of a similar or larger scale, though SolarWorld has made no definitive plans to do so.

Following the production flow

At one end of the Hillsboro factory, operators load charges of virgin and recrystallized scrap polysilicon into one of the dozens of crystal furnaces. The materials are then spun-melted and formed into single crystals and pulled into ingots, after which they are transported to a cropping and squaring area. The two-metre-long rectangular loaves of processed silicon are then taken to the cutting area, where they are sliced into ~200µm-thick wafers by a phalanx of whooshing wiresaws collectively containing spools of thousands of kilometers of diamond wire, most of which must be replaced after being used for a single cut.

The 156-mm wafers' surfaces are further prepped, cleaned, and inspected before they are either kicked back for additional reprocessing or binned and then placed in cassettes to move into the cacophonous cell-processing area, where the silicon squares are processed, screen-printed, and cleaned before becoming high-efficiency mono cells. After yet another round of thorough quality control checks, the bluish cells are shipped to Camarillo to be placed into modules.

There, the glass is prepped and the cells are linked 12 to a string, 6 strings to a module, and the units are laminated, backsheeted, j-boxed, and framed into glass PV panels, each flash-tested for its power output capabilities. The finished Sunmodules go through a final manual inspection and, if they pass muster, are then stacked according to wattage and finally loaded 40 or so at a time into sturdy shipping boxes.

Photo: Tom Cheyney

Gordon Brinser, VP of operations for SolarWorld USA's production facilities.

Acting as tour guide for my springtime visits to the Hillsboro and Camarillo factory floors, Gordon Brinser steered a fine line between filling in details about certain production flows or tool layouts and begging off on any further discussions of the secret-sauce elements that the German-owned company believes give it an edge on the competition. "How to integrate [the tools] and how to use [them] in a fully continuous line is where our intellectual property comes in," he told me.

As vice president of operations for SolarWorld USA, his responsibilities extend to both facilities (as well as the company's Vancouver, WA silicon plant). Brinser is a veteran silicon ops guy, having helped set up and run factories for Wacker Siltronic and Sumco in the Pacific Northwest and Singapore, but he's a relative newcomer to the solar manufacturing business, with about a year and a half on the SolarWorld job. With the plants running around the clock, seven days a week, at close to or at full capacity, Brinser has his hands full.

Meeting the challenges of the facility retrofit

Brinser has done facility retrofits and green-field construction projects during his career and readily admits that both approaches have their advantages and disadvantages. During our walk-through of the Hillsboro production area, we came upon an unusual tool-meets-factory layout quirk, where the back end of a texturizing wet bench fit snugly through the bottom of the inverted vee of a large girder – a "structural component" that wasn't on the architectural blueprints provided by Komatsu.

"That's one of the things about using a preexisting building", he explained. "You lay out the map and say this is where all our tools need

Photo: Tom Cheyney

SolarWorld USA's Hillsboro site, where ingots, wafers, and cells are produced.

to go and you start doing the construction. Because everything's done so quickly and in parallel, all of a sudden when you're in the middle of taking down walls and the layouts don't quite clearly show all the structural components of the building, and you open it up and say, 'oh shoot' – what do you do? Luckily, with the equipment, we had to move it a foot or two, so at least it didn't come down right in the middle of the tool. This was a surprise to us that these structural components were here – on the drawing, none of the girders were there."

"The thing with retrofitting an existing facility is, it's much faster, since a lot of the components are already there inside, so some of the long lead times are gone," he continued. "You already have the shell, so you don't have any weather issues to mess with schedules. You're under cover the whole time.

"[But] there are surprises that weren't completely documented. You have to live

Photo: Tom Cheyney

SolarWorld USA's Camarillo location, where module assembly takes place.

Photo: SolarWorld

A forest of crystal growers melt down the polysilicon and turn it into ingots.

under the constraints of this acid system, or a chemical delivery system may be in one part of the building but you need [it] someplace else, so it's not quite perfectly laid out the way you want it. I think we've made a very good balance of what we need and what was here, and at the end of the day, it's a state-of-the-art facility," he said.

Balancing automation costs, seeking better tools

Although SolarWorld touts both the Hillsboro and Camarillo plants as "fully automated," the reality on the shop floors is something different. Most of the lines are indeed populated by handling robots that whip wafers, cells, glass plate, and modules around with precise ease or conveyors continuously rolling steady streams of wafers/cells inexorably along the flow of production, yet a handful of processes still require the human elements of keen eyes, taut muscle, and technical savvy.

An example in Hillsboro is the wire-saw room, where ingots are still lifted and largely mounted manually onto the tools before being sliced into wafers, an area where Brinser admits he would like to see a higher level of automation. In the wafer cleaning area, after a batch of properly prepared substrates are placed inside the handling cassettes, a technician comes along and hauls the "boats" off the end of the machine. "It's a cost-benefit balance, in terms of automation," the VP said.

Down south in Camarillo next to the module line's cell-stringing equipment, we observed an inspector as she carefully examined damaged cells. "We 100% inspect visually," explained Brinser. "We have some stations here, because of mechanical handling, where operators take out the broken cells. She'll do a minisurgery, take it out, clean it up, and repair it. Any broken cells are sent back to Germany to be stripped down."

"Stringing is still very mechanical," he continued. "Lamination has been highly automated, and stringing's highly automated too, but with stringing there is still a lot of physical contact with the cell. Every time you touch it, you risk cracking it or chipping it. So for moduling, you put all this money in to get this nice cell and now you gotta handle it again. Advances for different stringing technologies would be very beneficial."

Another area where Brinser seeks better solutions from the suppliers is in the heart of the cell-fabrication area, where he'd like to see something done about the enormous footprint of the screen-printing systems (they take up about half of the floor space there) as well as improvements in the throughput and process capability of the equipment.

"Longer term, there's a lot of opportunity here in this process for more speed, better uniformity," he noted. "The less shading you can put on a cell, the more efficiency you'll get. Look how much footprint this thing takes up," pointing at a dozens-of-metres-long system. "When we talk about how to make the process a lot cheaper, how can you do this all in one single process step? How can you get twice as much or three times as much capacity out of this floor space?" He wondered aloud about some way of double-stacking the tools and reminded me that big footprint tools also carry a larger price tag in terms of their greater use of electricity, chemicals, and other not-so-fixed costs.

"Any place we can eliminate a process step, eliminate complexity – like going inline instead of batch – that's great," he said. "Volume for us is what's key. At the end of the day, it's about reaching grid parity," noting the company's ambitious roadmap to drive 10% out of its manufacturing costs each year.

SolarWorld works closely with its vendors, big and small. Some suppliers are more sophisticated because of years of experience working with (and being beaten up by) semiconductor manufacturers, while others come from the less-demanding specs of the machine-shop realm. "We're working very diligently with our suppliers to improve the quality," said Brinser. "You'd be surprised at some of the conversations we have with them. We start talking about capability and it's a foreign topic to them."

But the company is not just looking at its current needs from the upstream supply chain. "We look at best of breed for every single operation and say, 'what's the best today and are they going to get us to what we need in the future?'" he explained. "For the wiresaws we just went through a whole new analysis for our second expansion here, and we reevaluated all the manufacturers."

Pushing forward on the production ramp

The results of that reevaluation are bearing fruit, as additional wafering tools have been delivered to Hillsboro and will be making their first cuts by the end of August, according to Brinser. New silicon-ingot cropping and squaring gear has also arrived and will be part of a newly dedicated area adjacent to the crystal pulling room. Facility drop-downs are also in place, so "by the end of the third quarter, we should have all the major tools in their proper location," he said.

By October, tools will also start populating the new 210,000 sq ft building being built behind the current facility in Hillsboro, with operational capability coming online not long afterwards, explained Ben Santarris, a former business editor at the Oregonian who joined the company as its public affairs manager. The new addition, which will be split more or less evenly between logistics and production uses, will be dedicated in early October as part of the site's first anniversary celebration.

Brinser revealed that the new manufacturing space will be used for additional module assembly lines, "which will allow us to quickly add capacity, as needed." This move will make the Hillsboro campus a de facto vertically integrated facility and give the company even more flexibility to meet the demands of what could become the fastest-growing solar PV marketplace over the next decade.

The benefits of such soup-to-nuts integration are critical to SolarWorld's gameplan for success. "Being vertically integrated, you can align those quality parameters pretty tightly," Brinser said. "You can drive that quality real easily back all the way down the line to the source of where the quality problem exists, and you can fix it there. There's no hidden factor."

Photo: SolarWorld

A high level of automation greatly increases the capacity of the moduling line.

About the Author

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