

James Worden, Solectria Renewables Andrew Worden, Barron Partners and GameChange Racking

From Power Electronics to Racking Systems: Perspectives on Equipment Development, Manufacturing and Deployment

While there are a few notable instances of brothers working in the solar industry, it is uncommon. James and Andrew Worden are two such brothers. They operate distinct companies and apply their product development, manufacturing and business expertise to specific solar product classes and market segments.

In 1989, James Worden and his wife, Anita, cofounded Solectria Corporation, a developer and manufacturer of electric and hybrid vehicle components. They sold the business in 2005 and launched Solectria Renewables, shifting their focus to the design and production of PV inverters. Today, Solectria Renewables offers an extensive inverter product line, as well as

performance monitoring and BOS components. James holds a BS in mechanical engineering from Massachusetts Institute of Technology (MIT) and serves as Solectria's CEO.

Andrew Worden is the CEO and founder of GameChange Racking. He is also the chairman, CEO and majority investor of Barron Partners, a global cleantech investment firm, and the CEO of Soltas Energy, an EPC that develops and finances commercial and utility-scale PV projects (this company is in the final stages of being sold). Andrew graduated from Harvard University with a BA in physical sciences and studied engineering at MIT. He also studied finance and marketing at the MIT Sloan School of Management.

James Worden Solectria Renewables

SP: Since its founding in 2005, Solectria Renewables has continually expanded its inverter product family. What is the chronology of the company's inverter model introductions?

JW: Our first product was a 10 kW 3-phase commercial inverter that was originally UL listed in 2004 while we were still in the electric vehicle business. This inverter grew to become the PVI 10–15KW product line that is still sold today. The second introduction was our residential line, which started with 1.8 kW and 2.5 kW products and gradually grew to include models up to 7.5 kW. We introduced our PVI 50–100KW product family in 2005. Through the years we have continually upgraded each of these lines with new technologies, features and options. Our goal is to develop highly integrated inverter systems, increase system reliability, and reduce the total installed cost and labor at PV jobsites. Solectria inverter features include standard ac and dc disconnects, ac service entry ratings, and RS-485 and Ethernet communications. We have added fully integrated factory-built and tested options, many suggested by our customers, such as stainless steel enclosures, air filters, string combiners and subcombiners or recombiners. We introduced the first solar subcombiners that utilize circuit breakers, eliminating the



Courtesy Solectria Renewables

James Worden, Solectria Renewables James has more than 25 years of power electronics engineering and manufacturing experience. In 2005, he and his wife, Anita, cofounded Solectria Renewables. Today, Solectria offers an extensive inverter product line, performance monitoring and BOS components.

Solectria equipment is designed to operate for more than 20 years, so easy preventative maintenance and service are critical design features.—James Worden

need for external dc disconnects, as well as subarray monitoring, revenue-grade monitoring and even options for different disconnect orientations. In 2010, we launched our Smart Grid Inverter (SGI) line of 225 kW–500 kW inverters with the highest level of grid integration in the industry for this size inverter. In 2011, we brought our Megawatt Solar Stations to market. Last year, we introduced a new line of 3-phase transformerless string inverters ranging from 14 kW to 28 kW. This year we are rolling out a completely new line of transformerless 3.8 kW–7.6 kW residential inverters and 500 kW–750 kW 1,000 Vdc utility-scale inverters with external transformers.

SP: Are there technical advantages to integrating Solectria's monitoring products and BOS equipment with Solectria inverter systems?

JW: Historically, we offered products closely related to the inverter because we could design and build a cost-competitive product. In 2007, we introduced SolrenView web-based monitoring, and in 2008 we introduced string combiners. However, our inverters were always agnostic to monitoring and combiner solutions. Going forward, that is changing a bit, as more controls and monitoring are being requested and required in the combiner box, such as arc-fault detection, string monitoring and rapid shutdown. An integrated, complete solution has more synergy.

SP: How does Solectria address an inverter's reliability and serviceability during its design phase?

JW: Solectria Renewables emphasizes reliability and serviceability as top-level

goals at all phases of design. We have the benefit of 25 years of power electronics engineering and manufacturing experience from our electric vehicle history. Electric vehicle power electronics needed to be reliable and lightweight, and to operate in the harshest of conditions. These same features serve us well today. Lightweight products are easier to service. The field-swappable sealed power stage used in our central inverters increases reliability and durability and greatly reduces service time. This keeps uptime at a maximum in the rare event that a problem occurs. Solectria equipment is designed to operate for more than 20 years, so easy preventative maintenance and service are critical design features. For hardware design, MTBF [mean time between failures] and useful life targets are carefully developed and measured for optimal life and low-failure rates. For software, robust implementation of features such as automatic recovery from disturbances and rejection of site-specific issues such as system variation are critical goals. Solectria has developed extensive reliability guidelines for all designs from our decades of high-power inverter experience. Reliability tests are performed on every design, including HALT [highly accelerated life test], long-duration testing and environmental stress testing.

SP: In October 2013, Solectria launched its 1,000 Vdc SGI 500XTM and SGI 750XTM central inverters. How rapidly do you expect system designs to transition to 1,000 Vdc in the US, and in what market segments in particular? Do you see any significant obstacles to this transition?

JW: Solectria has always taken the position that one size does not fit all.

This is why we offer one of the most comprehensive product suites today, including a large array of 600 Vdc products. We have added 1,000 Vdc units in both 3-phase string inverters and 500 kW–750 kW central inverter models. The 1,000 Vdc adoption will depend on local electrical and safety codes. Large-scale ground-mounted projects have and will continue to be the first adopters. Economic forces move developers to 1,000 Vdc, but compliance with electrical and safety codes always wins. Currently, 600 Vdc systems are established, proven reliable and economic, and for these reasons they will continue to be a significant segment of the market.

SP: California's Rule 21, which is currently being revised, addresses interconnection, operation and metering requirements for distributed generators. What is your perspective on the Rule 21 revision effort and the advancement of smart-grid inverter capabilities?

JW: Solectria Renewables is a strong supporter of advanced grid interface requirements such as California's Rule 21. We are active in the development of the new requirements to ensure optimal implementation in our products. Solectria has multiple advanced pilot programs with utilities in California and elsewhere to prove performance to the new Rule 21 requirements. Many of our customers have been asking for more smart-grid capabilities that are not currently allowed under IEEE 1547. One example is active grid-voltage regulation to avoid inverter tripping on high-line or higher-impedance ac output circuits. Many customers in this situation could get higher overall system energy output when the inverter is capable of scaling back output power slightly to avoid driving the ac line above trip limits at high-irradiance levels.

SP: Have Solectria central inverters been deployed in locations with high levels

of distributed generation (DG)? What special considerations do these applications present, and how is Solectria addressing them?

JW: We have deployed many inverters to areas with high DG penetration. We currently support adjustable maximum power limiting to help meet interconnection requirements, programmable ramp up/down rates for power production and customizable power factor configurations. Many other smart-grid features are in development and reliability validation for next-generation requirements such as Rule 21. High DG penetration will require more-advanced integration and communication with the grid and will help make the grid more robust.

SP: What is your perspective on central versus distributed systems? Do you expect distributed designs to gain traction in utility-scale projects?

JW: You never install solar in the same place twice, and each deployment has a unique set of challenges. In some cases, the challenges are best addressed with a central inverter; in some cases, with multiple string inverters. The dynamics of each installation dictate the right solution. Solectria's ability to offer cost-competitive solutions in 14 kW–28 kW 3-phase string inverters for 600 Vdc and 1,000 Vdc designs increases the number of situations where this becomes a viable or even preferred solution. Using large central inverters for utility-scale plants is still the dominant approach. We expect that to remain consistent. Medium-size fully integrated 50 kW–500 kW central inverters are perfect for systems where a transformer is required or desired, or where designers prefer fewer individual inverters at a site.

SP: Does Solectria have plans to develop products that integrate solar energy storage? If so, what market segment will be the initial focus?



Courtesy GameChange Racking

Andrew Worden, GameChange Racking Andrew is the CEO and founder of GameChange Racking, which manufactures roof, ballasted ground-mount and post-driven ground-mount racking structures for commercial and utility-scale projects. He is also the chairman, CEO and majority investor of Barron Partners, a global cleantech investment firm.

JW: Solectria Renewables is poised to provide state-of-the-art hardware that can integrate with either short- or long-term energy storage. The technology in our inverters today can support any number of storage solutions. Due to our background in electric vehicles, rapid vehicle charging stations are a particular interest.

Andrew Worden Barron Partners and GameChange Racking

SP: You serve in an executive capacity at Barron Partners and GameChange Racking. How do the companies complement one another under your oversight?

AW: Barron Partners has invested more than \$480 million since 2002, most heavily in cleantech manufacturing companies. This background allowed Barron to build contacts in the finance community

that help us provide capital introduction services to GameChange Racking's customers. With our background in metal fabrication at Barron, and my combined educational background in engineering and finance, I saw an opportunity to build an extraordinary PV structure company. We founded GameChange Racking on the premise of bringing double value to customers: labor cost savings from fast install plus cost-effective racks. We were able to validate many generations of products for roof and ground systems on our own plants, greatly accelerating the product development curve. Once we felt that we had well-developed products at a very compelling value, we initiated ETL testing to the UL 2703 and UL 467 standards, and wind tunnel testing. We launched the company to the marketplace about a year ago, and the market has enthusiastically received our products. We have

grown dramatically, with rapid sales growth nationwide for our roof systems, ballasted ground-mount and post-driven ground-mount systems.

SP: Over the last several years, numerous companies have entered what appears to be a crowded racking manufacturing space. Considering these market conditions, how do you differentiate GameChange's products?

AW: Our products enable fast installation due to patented engineering innovations, such as GameChange's Pour-in-Place ballasted ground-mount technology, a snap-together roof system and a seamless-fit post-driven system that eliminates all brackets. We offer value pricing for high-quality products that carry a 20-year warranty. Additionally, we offer racking system engineering stamps in 31 US states.

SP: GameChange offers low-slope roof, and post and ballasted ground-mount racking systems. Are you seeing a significant growth trend in one product line or a particular application?

AW: All systems are showing dramatic growth for GameChange; however, the Pour-in-Place Ballasted Ground system is a substantial innovation. As such, we are seeing the largest potential growth rate in that product.

SP: What efforts is GameChange making to drive cost out of commercial and utility-scale racking systems and their installation?

AW: Our product designs eliminate racking system components, which in turn speeds installations and drives down installation costs. Our purchasing power reduces costs through bulk metal buying. In addition, we utilize

certain methods that greatly reduce labor cost in manufacturing.

SP: Where are GameChange Racking's manufacturing and warehousing facilities located? Why were these particular locations selected?

AW: Manufacturing and warehousing locations are selected based on proximity to customers and on local labor rates. GameChange Racking manufactures its products at facilities in Kansas, Massachusetts, Ohio and Texas, and warehouses in Kansas and Massachusetts.

SP: What is the status of GameChange's UL 467 and UL 2703 certifications?

AW: We have completed ETL testing to the UL 467 and UL 2703 standards for all of our roof and ground-mount systems. Also, in January we completed wind tunnel testing for our complete

My roots as an investment fund manager have helped me understand what solar investors require: total system cost reduction while meeting the demands for bankability.—Andrew Worden

product line. Wind tunnel testing is becoming increasingly important for customers to see that their support structure vendor has accurate loading data to correctly engineer structure material strength as well as ballasting and embedment requirements.

James and Andrew Worden

SP: Why did you decide to enter the solar industry? Was one of you instrumental in getting the other involved?

JW: I had been involved in renewables since I was in high school. I built a solar electric car that inspired me to move on to engineering and MIT. I focused on electric vehicles for many years after MIT as the cofounder of Solectria Corporation, along with my wife and partner, Anita. We were fortunate enough to build a successful business. Solectria engineers were experts in power conversion, so it was a natural progression to offer a solar inverter that could be used to power your home and recharge your car. In 2005, we sold the electric vehicle segment of Solectria to focus entirely on PV inverters and accessories for the solar space. I look back over the past 25 years and feel like the luckiest person alive. I have been able to lead a great team, creating US manufacturing jobs, pioneering some of the most advanced solar technology today and knowing we are having a positive impact on the planet.

AW: Barron Partners has had investments in the solar industry and metal fabrication since 2004, primarily because we believed that cleantech was the right thing to do ethically and that it would eventually become

cost-effective competition for fossil and nuclear energy. Over the last 8 years, I watched James and Anita lead Solectria at a dramatic growth rate despite high solar module prices, which piqued my interest in PV. When module prices dropped under \$1.50 per watt, I saw that the numbers were penciling out to invest in solar projects and that the time had arrived for PV to really scale. We started Soltas Energy as a wholly owned subsidiary of Barron Partners and built many rooftop and ground-mounted solar plants, ranging from 370 kW to 3.5 MW in capacity. As Soltas built these plants, we felt that there was a lack of cost-effective, easy-to-install PV support structure solutions. We have now signed an agreement to sell all of our operating power plants and to exit that business to focus totally on GameChange Racking.

SP: What is the level of your involvement in each other's business ventures? Do you work together on specific system installations?

JW: Solectria Renewables and Andrew's businesses are separate and have no relation (no pun intended). That being said, my brother and I are in complementary segments of the business, so we don't have the same competitive interests as we had in high school, when we both liked the same girl, but I digress. Andrew and I are both committed to the betterment of the industry as a whole. In our minds, the success of the solar industry is good for everyone. We share ideas on how the industry can become more cost competitive, while maintaining a healthy long-term business proposition.

AW: We help each other brainstorm about general industry trends and how to help customers meet their PV system needs. We have no active involvement in each other's businesses. However, our products are often installed in the same projects, which is great to see.

SP: What are your short- and long-term goals for advancing the North American PV industry? What key issues does the industry need to address?

JW: There is no doubt that cost is always at the front of everyone's mind. We have come a long way, and in many regions, solar is already at grid parity. The solution will not be a single component; it will be overall system designs becoming more cost effective. Streamlining soft costs as well as BOS costs will propel the industry to the next level. Educating customers about the value of solar is also critical. Many people do not fully understand the true value that solar offers. Of course there's the value of the renewable power generation, but there is also an incredible set of grid control features we can offer utilities that can offset other capital investments and improve grid quality and reliability. As an industry, we can offer a distributed energy generation model that future generations will be proud of.

AW: My roots as an investment fund manager have helped me understand what solar investors require: total system cost reduction while meeting the demands for bankability. Now that module prices have dropped dramatically but stabilized, BOS cost reduction is the hotspot requirement for PV to reach grid parity more widely. At GameChange, we are fortunate to be able to make a difference for our customers because we offer systems that are not only cost effective, but also fast to install. This has been a critical differentiator in closing our larger customers, who are not accepting overpriced industry offerings just because certain companies are bankable. ☺