

Technical Executive Summary

Overview and Vision

Natcore is a research and development company pioneering solar cells with improved efficiency and reduced cost. By combining world class expertise in the solar community with a well-equipped research facility, we are developing approaches that will define the next generation of cells. Our output is technology: we currently have 65 patents granted and pending. Natcore plans to move our technologies into manufacturing through partnerships that ultimately yield licensing and royalty revenue streams.

Primary Technology: Natcore Foil Cell (Laser Processed)

The vast majority of solar cells produced today employ front contacts—one of the cell's electrical contacts is the familiar grid of metal lines on the front of a cell. Even though the grid lines are thin, they block light and thus reduce efficiency. These standard solar cells are also made with a thermally diffused emitter, requiring very high process temperatures (>800C). The combination of front contacts and thermally diffused emitters limit current cell efficiency to about 19%.

Recently, a 25.6% efficiency was reported – the highest efficiency ever reached for a silicon solar cell. The cell in question used only back contacts, thus blocking no light. It also used a silicon heterojunction (SHJ) emitter, eliminating high temperature diffusion steps. While the achievement showed the value of these approaches, the cell was produced using a complicated, high cost process. The goal then: produce a cell like that at low cost.

The Natcore Cell leverages laser processing and a revolutionary approach to contacting/metallizing the cell in order to drive out cost while getting to high efficiency.

Our design requires highly defined regions of heavily doped silicon in order to form the base contact of the solar cell. By using a powerful focused laser beam, small regions of the silicon surface can be melted in the presence of a specially applied dopant, allowing that dopant to penetrate the silicon matrix. In particular, Natcore scientists have discovered a method to laser-form these dopant regions while not disrupting the high quality emitter already present on the solar cell. The laser process is rapid, and can be performed in low capital equipment at atmospheric conditions.

Our approach to metallization is game changing. Silver is a staple of current solar cells, being used for its high conductivity and easy processing. However, it can represent from 30 to 50% of the fabrication cost of a solar cell. Our unique metallization approach relies upon a simple multilayer structure composed of aluminum foils. The use of aluminum alone permits great cost saving. However, there are two additional areas of cost saving with our approach. First of all, the metallization process, leveraging the worldwide volume of aluminum foil production, can have a very low capital cost and footprint. Secondly, the resulting cell architecture is ideal for subsequent incorporation into modules cheaply and with low cell-to-module (CTM) losses.

Natcore has specifically protected its laser back contacted cell approach with a number of patent filings covering the architecture, laser process, and general processing characteristics. Natcore's rapid progress in this area is enabled by David Carlson, member of our Science Advisory Board and Charlie Gay, auxiliary scientific advisor. Both bring a recognized, extensive career in solar technology and business to the table.

At the request of two large solar cell manufacturers, Natcore was asked why our technologies were important and how they will help them. In response to that request, our CTO, current and auxiliary scientific advisors prepared the following:

- Natcore makes solar energy cost-competitive by increasing efficiency and lowering cost.
- In a solar cell industry where manufacturers are fighting for fractions of a percent improvement in performance or costs, Natcore's new cells will offer cost/watt improvements likely well over 30% – a generational leap in performance that will essentially force adoption by the industry.
- Natcore will have a very quick ramp-up to significant revenues, with virtually no capital expense and margins near 100%. This is because the company's business model calls for licensing the technology to any and all comers, earning royalties on equipment, materials and every solar cell sold using the proprietary process.
- Natcore's scientific staff, current and auxiliary advisory members boast some of the world's top experts and authorities in photovoltaics, highlighted by Dr. David Levy (former Senior Research Scientist at Eastman Kodak); Dr. Charlie Gay (former Director of U.S. National Renewable Energy Lab, president of Applied Solar at Applied Materials, chairman of technical advisory board of Sunpower); Dr. Dennis Flood (former Chief of Photovoltaic and Space Environments Branch, NASA); and Dr. David Carlson (former Chief Scientist for BP Solar and inventor of the amorphous silicon solar cell).

Dr. David E. Carlson

- Ph.D. in Physics from Rutgers University, B.S. degree in Physics from Rensselaer Polytechnic Institute
- U.S. Army Nuclear Effects Laboratory, R&D Physicist
- RCA Laboratories, Photovoltaic Device Research, Group Head
- Invented the amorphous silicon solar cell
- Solorex Corporation Vice President, Chief Technologist, General Manager, Deputy General Manager and Director of Research Thin Film Division
- BP Solar Chief Scientist for Future Technology programs and Intellectual Property System
- Received the Morris N. Liebmann Award (IEEE) for crucial contributions to the use of amorphous silicon in low-cost, high performance photovoltaic solar cells
- Awarded the Walton Clark Medal by the Franklin Institute for innovations in the use of hydrogenated amorphous silicon for solar energy conversion
- Received the William R. Cherry Award for advancement of photovoltaic science and technology
- Received the Karl W. Boer Medal from the International Solar Energy Society and the University of Delaware for outstanding contributions to the field of solar energy
- IEEE Fellow and a member of American Physical Society, the American Vacuum Society and Sigma Xi
- Holds 26 patents, 8 pending, published 150+ technical papers, listed in Who's Who in America



Dr. David E. Carlson

Natcore is establishing a strong proprietary position in a new type of back contact solar cell that utilizes aluminum rather than silver, and the Natcore process promises significantly lower cell and module costs with the potential of high performance (20% +). Natcore is on a research and development path to demonstrate high performance, low-cost, back-contact solar cells in the next few months.

Just the appearance of the Natcore back-contact solar cell will show anyone working with PV that the technology is completely different than anything currently on the market.

Dr. Charles Gay

- Ph.D., Physical Chemistry; University of California, Riverside
- Elected to the U.S. National Academy of Engineering for his seminal leadership contributions to the development of the global solar PV industry
- Founder of Greenstar Foundation to deliver solar power and internet access for health, education and microenterprise projects to developing world villages.
- Applied Materials; President, Applied Solar; Corporate Vice President
- SunPower; Chairman, Advisory Board
- ASE Americas; President and Chief Executive Officer
- U.S. National Renewable Energy Laboratory; Director
- UNISUN; Co-Founder and Managing Director
- Siemens Solar Group; President, Member-Executive Management Com.
- ARCO Solar; President
- BCleantech; Member, Advisory Board
- BT Imaging; Member, Board of Directors
- Halo Industries, Advisor
- Plant PV; Member, Scientific Advisory Board
- Siva Power; Member, Technical Advisory Board
- FlexFlange; Partner
- SimuSolar Tanzania, Advisory Board
- Enki Technology; Member, Board of Directors
- Dragonfly Systems (now a SunPower Company); Member, Advisory Board
- Holds numerous patents for solar cell and panel construction and is the recipient of the Gold Medal for Achievement from the World Renewable Energy Congress.



Dr. Charles Gay

1. **Leadership vision: lowest cost PV module with highest efficiency**
 - Technology clock is ticking at mean 0.6% absolute efficiency increase every 12 months.
 - Existing players are VERY slow to evolve due to lack of R&D (due to cost savings measures) and preference for being the first second in new technology manufacturing and are under pressure to transition to next generation platform.
 - ◆ This leaves the opportunity to capture market share with the performance premium (20+% MODULE efficiency) at lowest cost
 - ◆ Natcore's near term concept integrates cost savings at cell level with module cost savings (press releases)
 - ◆ Natcore's design delivers maximum kWh/W, which is critical for YieldCo optimization (e.g. TerraForm, 8Point3, etc.)

- ◆ PV packaging technology may also be relevant to optimization of thermal dissipation in LED packaging (relevant to Luminus)
- ◆ Natcore has a roadmap to very high efficiency four terminal tandem (high bandgap laminated to all back contact crystalline silicon)
- ◆ Crystalline wafer producers are scaling high lifetime n-type crystal growth (e.g. Longi is adding 2GW capacity this year and 3GW next year)
- ◆ Natcore maximizes benefits of mono n-type cost reduction
- ◆ Natcore has visibility to kerfless wafer formation from mono
- ◆ Advanced diamond wire in the interim
- ◆ Multi is falling by the wayside

2. Scalability – speed of execution

- Existing alliances / partnerships
 - ◆ Technology: Fraunhofer ISE; NREL
 - ◆ Equipment: Eurotron, plus discussions underway with Meyer Burger, Applied Materials, various select China tool producers.....
 - ◆ Materials: Discussions with Coveme, DuPont.....
 - ◆ Fab A&E discussions in several geographic regions including US, China and Brazil
- Fab design compatible with lowest cost distributed manufacturing at 250MW scale competitive with cost structure of centralized 2GW scale

3. Team

- In house R&D Base
- Top notch advisory board with world class pragmatic scale-up experience

4. New York presence

- Availability of state support PLUS DoE support
 - ◆ Opportunity to leverage next cycle of SunShot funding: FOA No. DE-FOA-0001387 <https://eere-exchange.energy.gov/>
 - ◆ b. Proximity to resources of US PV Manufacturing Consortium (US PVMC) <http://www.uspvmc.org>

Dr. Dennis J. Flood

- Chief Technology Officer & Co-Founder of Natcore
- Chief of the Photovoltaic and Space Environments Branch at the NASA Glenn Research Center
- Chair of the Institute of Electrical and Electronics Engineers (IEEE) Photovoltaic Devices Technical Committee
- Serves on the International Advisory Committees of the European, the U.S. and Japan/Asia
- Serves on the organizing committees for World Photovoltaic Conference



Dr. Dennis J. Flood

The Natcore connections to Suntech and Suniva are straightforward. Both are solar cell and panel manufacturers and both are (or will be) looking at SHJ (the generic name for HIT) cell structures to reach the ultimate high efficiency for silicon cells. Both will ultimately want IBC cells. In fact, Suniva has been developing an IBC cell on an n-type mono wafer and is aiming at 22% in production.

Suntech has been looking essentially at all the advanced cell types (PERC, PERL, etc) and has put some into limited production.

Natcore's technology has the potential to take either or both of those companies (Suntech and Suniva) to higher levels of efficiency at a lower cost per watt compared to the cells they make now.

“Best-of-Breed” Consulting Program

In brief, our best-of-breed business model entails Natcore contracting as a consultant on the design and construction of solar cell/solar panel fabrication facilities and power plants, with compensation on a “cost-plus” basis as well as unencumbered equity in the project.

Natcore will guide clients in procuring components of the highest quality at the best prices available in the world, taking advantage of our preferential status in the industry. For example, since we are not a manufacturer ourselves, we have no biases as to which components to buy or which vendors to employ. Thus, we can provide the best-of-breed product with appropriate warranties and efficiencies.

It's important to note that Natcore is entering this arena due to numerous requests by companies and countries to aid them in developing solar cell facilities. These requests have come as our technology has moved dramatically closer to commercialization and gained a high profile in the industry.

For example, we have manufactured, in conjunction with Red Solar, the first black silicon solar cells created in an actual solar cell fabrication line. (All others have been made in laboratories, typically using exotic materials or applications that are not transferable to actual manufacturing.) Our black silicon application has been projected by NREL to reduce the cost to manufacture cells by 20%. Our laser processing will further reduce costs and increase power output.

Importantly, our black silicon and laser processing technologies will work hand-in-glove, transforming the solar cell production process and making our technology indispensable for manufacturers.

This is why we developed our best-of-breed business model — to give companies and countries an opportunity to have, as a worst case scenario, the best and most efficient solar cells and modules that exist with current technology. Additionally, our partners will enjoy some level of exclusive access to our technologies as they are commercialized.

Here are some of the unique advantages Natcore offers potential best-of-breed clients:

- First and foremost is our technology, which is recognized throughout the industry as being among the most advanced in photovoltaics.
- Our relationships are worldwide, so we are not restricted to certain geographical regions.
- Because of our leading-edge technology, many cell and module equipment manufacturers give us preferential treatment in order to have access to our applications as they become available commercially.
- Members of our Scientific Advisory Board – especially Dr. Daniele Margadonna – has vast experience in designing and building turn-key solar cell fabs.
- Our scientists are intimately aware of developments and advances in the solar industry.
- We have an exclusive license from the U.S. Department of Energy’s National Renewable Energy Laboratory (NREL) to develop and commercialize a line of black silicon products based on NREL patents. Those patents, along with our own, will be essential in building the solar cells of the future.

Because of these advantages, Natcore has entertained many inquiries from groups looking to develop solar cell facilities, and is in advanced discussions with a number of well-positioned potential partners.