TransTech Alert
Transformational Technology

Room-Temperature Ambient-Pressure Nanotechnologies Change the Solar Game

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Dear TransTech reader,

For investors, it's important to know where you shouldn't put money as well as where you should. Frequently, both decisions are determined by rapidly evolving technological change.

Periodically, I'm asked what financial sectors investors should avoid. My short answers to the question, for the past decade or so, have been solar energy and "old media." Believe it or not, both answers were actually controversial when I first gave them.

Many analysts were convinced that old media, when they first headed south, were going through one of their periodic down cycles and would come back stronger than ever. Given the growth of the Web, this was an astonishing and ultimately unfounded confidence in the status quo. New media, empowered by the Web, were permanently throttling the old-media revenue model, but investors lost billions before this obvious technological dynamic became clear to them.

The solar industry, many believed, was destined to prosper due to the myriad subsidies showered on it. Obviously, those who believed this had never read the work of Milton Friedman nor other economists who explained why subsidies pervert markets and technological development. In fact, subsidies were the reason to avoid solar.

While solar energy is a promising technology, the benefits have been consistently overstated due to complementary interests of cynical businesses and scientifically illiterate environmentalists. Both groups encouraged subsidies by making completely unrealistic claims about existing solar-cell technologies while preaching a CO_2-based climate model that has utterly failed to model the last 17 years.

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Solar boosters have also ignored the fact that current solar-cell production technologies rely on plasma-enhanced chemical vapor deposition (PECVD) and other astonishingly toxic and energy-intensive manufacturing processes. In terms of total product lifecycle analysis, solar energy is actually among the dirtiest of manufacturing technologies. There is nothing more ironic than a "green" sticker on a solar array when you understand that making the solar cells created pollutants that would get any other industry vilified, if not banned.

I feel the same way, incidentally, when I see electric vehicles that are actually powered upstream by coal and nuclear power. I have nothing against either of these power sources or electric cars, but the notion that vehicles charged by electricity produced by traditionally fueled power plants are somehow "clean," just because they outsource their exhausts, is willful ignorance. I haven't even addressed the environmental problems associated with batteries.

This same willful ignorance drove subsidies to the solar industry, befuddling technological progress in the process. Government subsidies, by their nature, institutionalize specific technological approaches, usually in industries that are new and evolving. In the solar-cell industry, we saw that marginally superior technologies offering incremental improvements in technology and cost were often kept out of markets flooded by inferior but massively tax-subsidized solar cells. It's generally agreed, in fact, that it would take a doubling of solar cell efficiencies or a halving of costs to produce solar cells capable of competing without subsidies.

Research has continued, but it has usually been academic and disconnected from the marketplace. Destructive subsidization has come not only from the US; China, Germany, and Japan have also played the game, all hoping futilely to build permanent advantages for their economies.

So I'm as surprised as anybody to find myself recommending a solar-cell company. The time, however, is right. Internationally, subsidies have failed. In the US, Suntech, Solyndra, and Evergreen Solar have not only crashed and burned, they've embarrassed those who promised they would create "green jobs" and profits. Hundreds of millions of dollars—probably in excess of a billion—have been squandered on ideological solar efforts. Moreover, they've left a mess in their wake. Jason Dearen of the AP reported in February 2013 that just 17 companies in California alone had produced 46.5 million pounds of toxic sludge and contaminated water from 2007 through the first half of 2011.

Germany has also backed off solar subsidies for entirely rational reasons. At the same time, American and European opposition to Chinese subsidies, through international anti-dumping trade agreements, has prevailed. In truth, however, the Chinese seem to be recognizing their own financial constraints while losing faith in their dream of dominating world solar-cell manufacturing.

The NASA-Rice University Nanotechnology Connection

Though it is virtually impossible to do research today without at some point using a lab that gets federal money, the company that I'm bringing you today has never received dedicated government subsidies. Nor has anyone in the company ever romanticized solar power to me.

The scientists and executives of this company do not pretend that solar energy will somehow replace all other energy sources and usher in nirvana, but they do believe their technology will allow solar energy to achieve grid parity in many parts of the United States and elsewhere. I'm convinced that their technology will, in fact, double the efficiency and halve the cost of solar energy production. And once the total lifecycle cost of solar cell energy is equal to the cost paid to power companies for electricity, many consumers and businesses will choose energy independence.

The company is Natcore Technology, Inc. (NXT.V). Currently, Natcore is listed on the Canadian TSX Venture Exchange (TSXV), but the company's shares are also traded in the US via "pink sheets," listed under the symbol "NTCXF." Natcore's CEO told me that the company is also in the process of filing a Form F-1 Registration Statement with the SEC to become fully reporting and listed in the US, which should increase volume and perhaps price. In Germany, the company is listed on the Frankfurt Stock Exchange as "8NT."

Essentially, Natcore has developed technologies that completely revolutionize the way solar cells are manufactured, eliminating most of the toxic wastes and expensive high-temperature requirements while improving solar-cell efficiencies and costs. These are not marginal improvements in solar cell technologies—they are transformational.

Natcore's scientists have developed ways to replace the high-temperature, high-waste fabrication technologies with revolutionary procedures that use simple chemical deposition employing commonly available materials at room temperature. Not only do these new technologies eliminate the most serious toxic waste problems and lower costs, they also improve the ability of solar cells to utilize and convert available light to electricity.

Natcore's platform is vast, starting with a simple way of cheaply harnessing more available sunlight using the current generation of silicon solar cells, and expanding to inexpensive room-temperature manufacturing of the high-efficiency quantum dot solar cells of the future. I'll explain a bit about how the manufacturing works later, but first let me give you some of the history behind the company's technology platform.

How Room-Temperature Chemical Deposition Was Born

Sometimes, the right two people are far more creative and productive than the sum of their individual parts. This is clearly the case with Dr. Dennis Flood and Professor Andrew Barron.

Flood was a 33-year NASA scientist who served as chief of the agency's Photovoltaic and Space Environments Branch, located at the Glenn Research Center in Ohio. He has also chaired the prestigious Institute of Electrical and Electronics Engineers (IEEE) Photovoltaic Devices Technical Committee and currently serves on the organizing committees of the World Photovoltaic Conference.

Around 2001, shortly after he left his position as the top NASA photovoltaic scientist to work instead with a small startup, he called Professor Andrew Barron, a noted English nanotechnologist who has published over 350 peer-reviewed scientific papers. Barron is the Welch Chair of Chemistry and Professor of Materials Science at Rice University, one of the world's top nanotech research centers. (It is also, coincidentally, the alma mater of our host, John Mauldin.)

Flood told me that he "got acquainted with Andy Barron through work at NASA looking at new chemistry that would passivate [protectively coat] the surface of a particular space solar cell we were developing. That turned into a small company for Andy and a friend from Harvard that was ultimately purchased and did moderately well.

"As a result, Andy and I started talking and exchanging ideas. Back in 2001 or so, I asked him if he could put silicon dioxide on carbon nanotubes, and he thought it was possible. Two or three months went by, and I got a call one evening. He said, 'Okay, I've got silica-coated Buckyballs. What exactly are these good for?'"

Buckyballs, as you may know, are spherical fullerenes, a category of carbon molecules that includes carbon nanotubes. These structures, named after Buckminster Fuller, were first produced at Rice University.

Though this conversation took place over a decade ago, Flood's reaction to it today remains sincerely awestruck. He recalls that Barron told him that he could coat fullerenes with silicon dioxide in a petri dish at room temperature on the laboratory bench. "Phenomenal," Flood told me. "Absolutely phenomenal."

And it is phenomenal. Silicon solar-cell fabrication accounts for about 85% of solar cells sold today. They, like microchips, rely on doping or coating silicon using processes that can reach temperatures of around 1,000° Celsius. This process is expensive, dirty, and often creates significant defects in electronic parts. The process accounts for about a quarter of total silicon solar-cell fabrication costs—and it can be eliminated entirely by using the processes that Barron invented.

It's instructive, or at least interesting, to ponder the way these two scientists' skill sets fit together. Flood, on the one hand, had been the top NASA photovoltaic scientist before he began working with Barron. He never had to concern himself with commercialization or budgets. Space missions need power. Solar cells provide a perfect solution. Since the cost of a solar cell's production is ultimately less than the cost of transporting that cell into space, he designed and bought the most efficient solar cells ever made for use in space. None of those cells made sense in terms of business. Paid by NASA to keep up with everything going on in the photovoltaic field, Flood was the ultimate big-picture guy.

Barron, on the other hand, is one of the leading experts on materials at the molecular level and is capable of solving nanotech problems even when he doesn't know why he's solving them. Talking to him, it struck me that I was talking to a consummate engineer, someone who naturally looks for the easiest and cheapest way to solve a problem. It is no exaggeration to say that Barron's room-temperature breakthrough is phenomenal, even historic.

I asked Barron how his deposition process actually works, and he referenced natural processes of growth of materials that rely on surface reactions. Bone and abalone shell growth, for example, yield sophisticated materials without high temperatures. Initially, Barron used Buckyballs to seed growth, somewhat like seeding an artificial pearl. Importantly, he also learned to initiate this growth on rod-shaped carbon nanotubes.

Barron's breakthrough, which he and Flood called the "liquid phase deposition process," made it possible to put silicon dioxide films on a host of different materials at room temperature, using commonly available industrial chemicals. Rice University patented this technology, and Flood and Barron helped form a new company that set out to license those patents. Initially, they weren't thinking about using the technology to make solar cells specifically, since it's applicable in a wide set of processes that presently entail heating silicon in the presence of oxygen to 1,000° Celsius or so. This includes, by the way, the production of standard microcircuits.

As is often case when dealing with universities, the process of acquiring IP rights was not going smoothly. The newly formed company's founding board chair, Brien Lundin, suggested bringing in an experienced CEO to handle negotiations with Rice. He suggested Charles "Chuck" Provini, a graduate of the US Naval Academy, who after leaving the Marine Corps had served as president of legendary Wall Street firms, including Ladenburg Thalmann Asset Management, Rodman & Renshaw's Advisory Services, and LaSalle Street Corporation.

Provini told me that Lundin had said that Natcore was a great company but was having trouble getting a contract with Rice. According to Provini, "Brien said he needed somebody who cleans up pretty good, has a decent résumé, and whose ego fits the size of his body. And I had two out of those three."

“My intention,” Provini told me, “was to help a friend out. He’d make me president, I’d get the job done with Rice, then find somebody to take my place, sit on the board, and go to board meetings in New Orleans where the other partners are. But before I got too involved in it, I wanted to make sure this wasn’t just a science project. I had been in the money-management business for 30 years, and I’d never recommended a stock. So the first time I associated myself with a company or a stock, I wanted to pay attention to it.

“So I went to the guys who used to work for me at Ladenburg Thalmann and Rodman & Renshaw, and I said, ‘If I wanted to do due diligence on something called nanotechnology, how would I do that?’ They gave me the names of a bunch of labs, one of which was Battelle Memorial Institute.

“I went to Dennis (Flood) and Andy (Barron). They said, ‘Battelle is a great lab; we do business with them and know them well.’ So we raised some money and went to Battelle and said, ‘Show us that this is commercial. Show us that it’s scalable, that this technology will work.’

“At the time, I was a consultant to the Moscow Stock Exchange, flying back and forth to Moscow for a couple of years. The biggest shareholder in the Moscow exchange was the president of a NYSE-listed technology company. After several months and meaningful amounts of vodka, we became good friends. I said, ‘You must have a lab.’ He said, “My CTO runs it. He makes US$60,000 a year.’ I went to his CTO and said, ‘I’ll give you $120,000 if you can show me this technology does not work and that it has no future. And I’ll give you $30,000 if you can’t.’ And I went home.

“Six months later, both Battelle’s investment arm and the Russian company came back and said they would like to be our partners for this technology. So I said, ‘We really have to find out what this technology is.’ I went back to Ladenburg Thalmann, Rodman & Renshaw, and investment banks and said, ‘I want to talk to the customers you cover.’”

At that time, Natcore thought it was going to be in the chip and fiber optic business, so the company surveyed both industries. As Provini says, “This whole process took me about two years.”

At that point—around 2005—Provini cleared the table so he could dedicate himself to running Natcore. Fast forward, and the company now has its own lab, which is run by Dr. David Levy, with whom I also spoke. Levy is a researcher and inventor who holds 78 patents in fields ranging from chemistry to semiconductors.

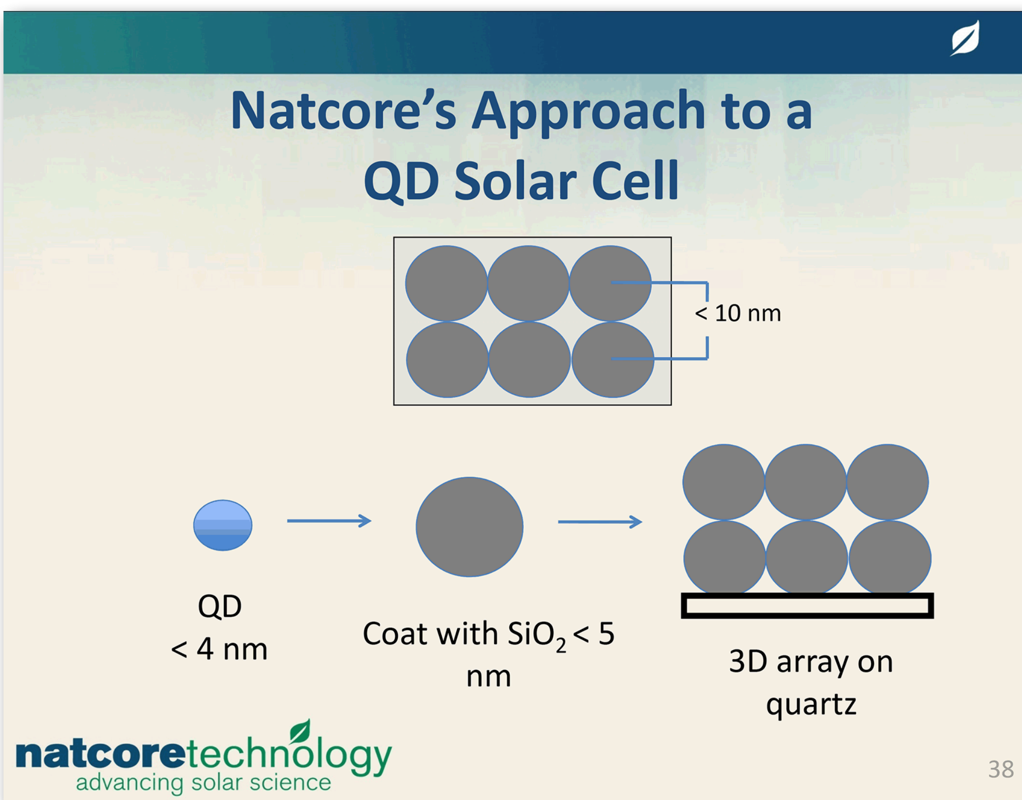
The Quantum Dot Breakthrough

Natcore has continued to add to its room-temperature IP library with 16 patents granted and 21 pending. In the long run, the most significant of these may be its quantum dot technology.

Quantum dots (QDs) are essentially nanoscale crystals. The size of a crystal determines is electronic characteristics. Those characteristics are neither like those of a single molecule of the component material nor like larger-sized particles or bulk materials. At the right size, however, electron valences seem to overlap so that outside forces such as photons create unusual and efficient energy transfers. Quantum dots can be made of materials such as germanium, silicon, or cadmium. Cadmium, however, is toxic and rare, while silicon and germanium are safe and available.

QDs are of particular interest to solar-cell scientists because they can be fine-tuned, by controlling their size, to convert light at specific frequencies into electrical energy at a very high rate of efficiency. The process also works in reverse, converting electrical into light energy for electronic display technologies.

The most efficient solar cells are thin-film tandem solar cells, which are used in satellites. They are called "tandem" because two layers (or more) of the right semiconductor materials will convert nearly all of the visible light spectrum into electrical energy. However, these solar cells are difficult, slow, and expensive to make. They're produced in vacuum conditions at very high heat, with all the attendant waste products.



Andrew Barron's original chemical deposition breakthrough, however, is directly applicable to QD solar cells. The company has produced quantum dots, coated them with silicon dioxide, and assembled them into 3D arrays at room temperature at ambient pressures. Best of all, the quantum dot layers Natcore is producing are a perfect match to the kinds of materials that are commonly used in thin-film devices. This means that they can integrate with, rather than disrupt, existing fabrication technologies.

Flexible thin-film solar cells have many advantages over conventional silicon cells, though as of now they are less efficient than conventional cells. One advantage is that they can be attached to any substrate, including windows and roofing materials.

Natcore's technology has the potential, Barron and Flood believe, to compete with and eventually beat grid-power pricing in many southern locations, at least during daylight hours. Of course, generating more electricity than is used, in combination with the right storage technology, would allow many people to get off the grid entirely. In places like Southern California, which is plagued with brownouts, solar would win. If these cells were durable enough to survive the occasional hurricane, even if the arrays required storm shutters, much of South Florida would convert.

Black Silicon

Of course, the current solar-cell industry is involved primarily with silicon cells. As Chuck Provini has pointed out, he's not interested in running a science experiment. Therefore, Natcore's platform involves rolling out a series of solutions for the existing solar-cell industry that will generate revenues by lowering costs and improving efficiencies. Dr. David Levy explained to me how the company plans to profit while moving toward its transformational quantum dot solar-cell technology:

"Let me start with 'black silicon,' because that's our nearest-term project. Silicon cells represent 85 percent of the market, but silicon is fairly reflective. If the surface is polished or fairly smooth, it reflects about 40 percent of the light, which is unacceptable because you lose 40 percent of the energy.

"The industry currently does two things to combat those losses. The first thing they do is texture the cell. They take this smooth cell, and they put it into a chemical bath. If you look at it under a microscope, it looks like it has little pyramids on it. So the light that hits that cell, instead of bouncing off, it might jiggle around a little bit between those pyramids and then bounce off. A smooth silicon cell reflects about 40 percent of the light. When you do that etching process, it still reflects about 12 percent of the light, which is still too much.

"Later in the conventional process, they put a thin layer of silicon nitride on that solar cell; and because of its optical properties, it takes that reflectivity down from 12 percent to about 2 to 3 percent. But this process is one of the most expensive processes in solar cell fabrication. It's a vacuum process. It also uses a hazardous and hard-to-handle gas called silane. Silane can spontaneously ignite at certain concentrations.

"We're working on a process that would replace texturing—the pyramids—with another wet process that doesn't just take the reflectance down to 12 percent but all the way down to 1 or 2 percent. This is the black silicon process. Instead of creating relatively large pyramids, it makes a much finer, porous structure. Because of the way light interacts with that structure, much of the light is routed into the cell. It makes the surface black. If you look at something that is 1 percent reflectant, it looks absolutely jet black. It looks a lot like black velvet.

"All of the low reflectance is due to that one process, and therefore we eliminate the expensive silicon nitride plasma-enhanced chemical vapor deposition step. We thereby attack the most expensive part of the process. A lot of the chemistries that we're using to do the black silicon are already common in the industry, so we feel it's something we could sell pretty easily. Right now, we're cost-modeling this in the lab, trying to improve our process to the point where we're ready to bring it to a manufacturer. We're pretty much at the point where we'd like to interest some external parties."

When asked about timing, Chuck Provini said, "We're sending 40 wafers with a black silicon coating to a solar cell manufacturer in China. The Chinese company will complete the solar cell process. We think they'll then have a solar cell with the same efficiency as their current solar cells, but it's going to cost them 23% less to make it. That step will probably be done by the end of January 2014. Then we will have shown that our black silicon process will keep the same efficiency but cut production costs by 23%. That is something we think we can go to market with.

"One of the members of our Science Advisory Board is Dr. Daniele Margadonna, who was the CTO of MX Solar in Italy. Daniele has built many turnkey photovoltaic plants and has bought tens of millions of dollars of equipment from the three major solar equipment manufacturers in Germany.

"We'll work with Daniele to take our results to these German manufacturers and ask them to build a piece of equipment using our technology that can be sold to solar cell manufacturers. If we get the results that we're hoping for in China, we'll begin knocking on doors after the first of the year. When does that turn into revenue? I suspect our first source of revenue will be some sort of licensing agreement with either an equipment manufacturer or a solar cell manufacturer, and I'm confident that this will happen in 2014, perhaps even within the first six months of 2014."

Also in the pipeline for near-term development is a room-temperature replacement for diffusion. This is the process of applying a chemical layer onto silicon and integrating it into the wafer at 800-900° Centigrade to achieve the desired electrical properties. This is also called "doping."

"There are a couple of bad things about doing that," Levy told me. "Number one, you never make a wafer better by heating it. You're basically causing more defects in the wafer."

The Natcore solution to the need for electrical connections on solar cells is astonishingly simple, though somewhat difficult to actually perform. They have found that they can apply the chemical layer and create the connections only where they're needed using lasers. As it happens, a member of the Natcore advisory board was chief technical officer of BP Solar before BP got out of the business. He had already decided that laser spot diffusion would improve the quality of solar cells while lowering costs and reducing toxic wastes.

Levy said, "He's been working with us, and we've been benefiting from his knowledge. We're also working with a professor at the University of Virginia who's already into that field. That's kind of our way of bootstrapping or accelerating our way into that project.

"While black silicon is good in a standard process, there's a solar cell structure that we're considering where all the contacts to the solar cell are actually on the back side. Normally, when you look at a solar cell, you see a grid on the front, and that side's the front contact. The entire front of the cell is one contact, and the entire back is the other. The laser process lets us put all of the contacts on the back of the cell. And in fact, the front of the cell, with black silicon for instance, only needs to be black and survive the diffusion process. You create a synergy if you make black silicon cells using laser processing. We're getting good at making conventional black silicon cells, and as we get closer to market, we want to leverage that experience into these laser cells."

Natcore has other projects in the platform, which I won't go into now. One, however, is an optoelectronics technology that can make an all-optical computer backplane. Utilizing photons instead of electrons, optical backplanes are expected to play an increasingly important role in microchip technologies.

Demand for Solar Cells Increasing While Subsidies Fall

Despite the worldwide economic downturn, photovoltaics have continued to experience an annual growth rate of 20-35% as prices fall. In the US alone, we're on target to install over four gigawatts of photovoltaic generating capacity this year. Worldwide, it's 35-38 gigawatts this year, and the figure is expected to continue to rise.

One of the most interesting aspects of solar energy is that so many oil-rich nations have perfect conditions for generating solar energy. On the surface, it might not make sense that Saudi Arabia, South Africa, or Australia would want to invest in solar energy when they export oil. This, however, ignores the political realities.

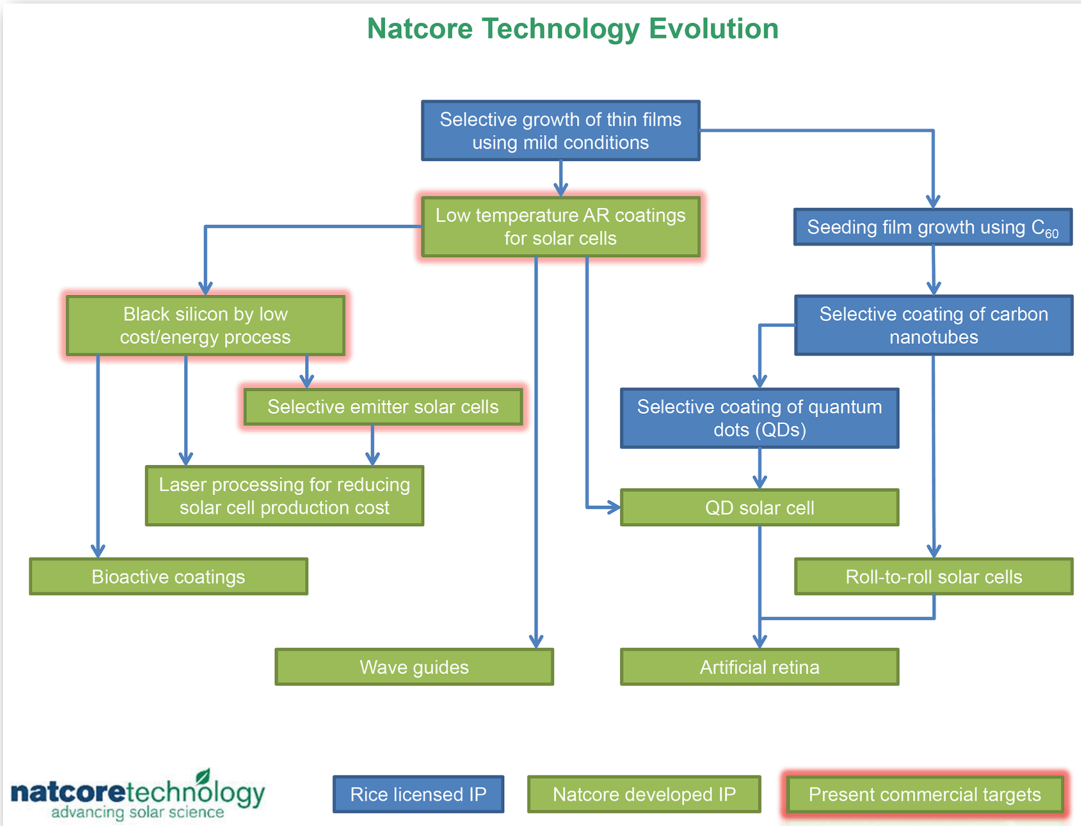
Local petroleum producers face enormous political pressures to provide petroleum for local power generation at low cost. In the case of Saudi Arabia, the oil companies are essentially giving away oil that could be sold on the world market. Provini told me that oil companies looking to replace petroleum-based electrical production contact him regularly. As they have plenty of money to spend on the technology, they are perfect customers.

Another interesting aspect about solar-power economics is that the biggest cost component is not the solar cell. Five years ago, half the cost of a solar array was the panels, which accounted for $3-$5 per watt. Today, fully assembled solar panels account for less than a dollar per watt. The rest of the cost of an array, regardless of size, is installation and maintenance. However, systems are being developed to address these costs. As the industry finally standardizes and matures, the cost of solar will be greatly reduced via improved installation technologies and robotic maintenance. Already, solar cells are being manufactured with guides for simple, cheap robot cleaners capable of improving panel-performance efficiency by five to ten percent.

I don't believe there's another company with the potential to compete with Natcore in terms of solar-cell efficiency and cost for the foreseeable future.

Chuck Provini sums up the Natcore game plan succinctly. "We basically have a handful of applications," he said. "Shorter term, we have black silicon, which is close to commercialization. Is it going to change the world? No. Will it make for great improvements? Yes. Will it get us revenue? Yes. We have a selective emitter process, and are putting our technology into the production line. We have two other applications. One is a flexible solar cell, a thin-film application. We put two layers of cells on it to improve efficiency. And then we have the tandem or quantum dot solar cell. We think the last two will have meaningful impacts on this industry and, in truth, the world. We think one will double efficiency and the other will cut manufacturing costs in half."

Further down the road, Flood and Barron are thinking about using carbon nanotubes to enhance light absorption and electrical conductibility, and to make possible a durable but flexible and inexpensive structure for roll-to-roll solar cells. I don't think anybody is going to regret buying this company and holding it for the long run. However, it's possible that it could license its black silicon technology very soon, leading to a much-increased revenue stream. The chart below shows Natcore's technological evolution, as well as the company's current commercial targets.



Obviously, this company is going to need additional coverage. The people involved are of the highest caliber, and I look forward to getting them all on video for you.