Green Engineering: Front lines of Cleantech

Bruce Rayner

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The way we live is defined by the fuel we use. Today it's oil. Tomorrow it will be a combination of technologies: hydrogen, solar, wind, geothermal, ocean wave and current, and most likely nuclear. The investment and innovation in these areas is exploding, and the race is on to establish cost-effective and scalable solutions.

For solar power, for instance, one of the key issues is the mass production of inexpensive photovoltaics (PVs). Another is the commercialization of new technologies, such as condensing solar thermal. The future challenge for all new energy solutions will be to build the infrastructure for getting the electricity from the power source to the customer, where the distance might be measured in thousands of miles.

For hydrogen fuel cells and rechargeable batteries for electric cars, it's all about setting up networks of refueling stations, much like today's gas stations.

Champions of renewable energy, including former vice president Al Gore and oil-tycoon-turned-wind-power-advocate T. Bone Pickens, are calling for massive investments in the power grid infrastructure. They are joined by organizations such as the Galvin Energy Initiative, which is bringing the debate to industry.

The only way to embrace renewable energy on a large scale, according to the Galvin Energy Initiative, is to make the grid "smarter" with digital controls and communications technology that will anticipate the natural fluctuations in wind and solar power to ensure that the power supply meets consumer demand. The investment required will be measured in the billions of dollars.

Market watchers and industry insiders suggest that these networks can be in place within the next five or 10 years. What follows are some examples of renewable energy innovations.

Solar: Economies of scale

While the wind turbine market garners the lion's share of investment capital, solar is a strong second place, particularly investments in thin-film PV and the burgeoning condenser solar market.

Overall, the worldwide solar market is projected to grow by 40 percent annually for the next few years, according to iSuppli Corp.'s Henning Wicht, senior director and principal analyst for microelectromechanical systems (MEMS) and PVs. After that, the pace will slow to a relatively modest 20 percent a year, projects Wicht.

"It's moving so fast that we're seeing meetings being pre-poned," Wicht said, referring to investor meetings that are moved up earlier on the calendar to close deals sooner.

One company on the forefront in thin-film PV technology is Nanosolar Inc. (San Jose, Calif.). The company is single-mindedly focused on mass producing thin-film solar cells from copper indium gallium selenide (CIGS) with the intention of driving the price per watt down so solar becomes competitive with more traditional energy sources.

In June, Nanosolar announced the first equipment capable of manufacturing 1 gigawatt (GW) worth of CIGS cells annually, or 100 feet per minute. That production rate is much higher than the average production rate, which typically produces 10 to 30 megawatts (MW) a year.

Nanosolar attributes the advance, in part, to its nanotechnology deposition process. The company is now ramping production of its thin-film PV cells, called SolarPly, at its 140,000-square-foot San Jose facility. The foil is then shipped to its 507,000-square-foot factory in Berlin, where it is assembled into panels. An initial project for Nanosolar's panels is a 1-MW installation by a German landfill company.

"The issue is cost, both product cost and capital efficiency," said Martin Roscheisen, CEO of Nanosolar. "It boils down to the cost per watt of the solar panel."

As the cost of solar comes down into the range of nonrenewable energy sources, the demand for solar panels will accelerate. Sources estimate that today coal costs between $1 and $2 a watt, while traditional silicon-based solar panels are hovering between $3 and $4 a watt. With its thin-film technology, Nanosolar believes it can bring the price down to around $1 a watt.

Lower prices will also help to thin the ranks of the competition. Lux Research, a cleantech market research firm, estimates there are more than 100 thin-film solar companies, a number of which have unproven technology.

"There's a lot of production out there," admitted Roscheisen. "Demand has been so strong, and a lot of investment has flowed into technologies that are not as competitive. As demand tightens, we'll see the market shaking out."

Fuel cells take flight

Earlier this year in Spain, Boeing had a Wright Brothers moment when it took to the skies in a plane powered by hydrogen fuel cells. Actually, it was a hybrid system consisting of a proton exchange membrane (PEM) fuel cell and a lithium-ion battery. This system powered an electric motor coupled to a conventional propeller.

Once the plane reached 3,300 feet, the pilot disconnected the battery and flew the plane for 20 minutes at about 60 miles an hour on just the hydrogen fuel cell.

For five years, researchers at Boeing Research and Technology Europe in Madrid, Spain, which is part of the Boeing Phantom Works R&D unit, had worked with researchers at Boeing Commercial Airplanes and a network of third-party companies to design, assemble and fly this experimental craft.

One challenge the researchers faced was to design a state machine that controlled the start-up and shut-down sequences of the electrical system. Another was designing a way to balance the power supplied by the fuel cell and the Li-ion battery during takeoff and climb.

Granted, this was no 747; it was a two-seat Dimona airplane, built by Diamond Aircraft Industries of Austria. In fact, Boeing does not envision fuel cells providing primary power for commercial airplanes. Rather, the technology may be a viable alternative to power systems such as auxiliary power units, which would help reduce airport noise and emissions.

The more immediate applications for fuel cells are in manned and unmanned military and surveillance applications, according to Boeing. With zero carbon dioxide emissions, very low noise levels and an insignificant infrared signature, fuel cells are well suited to these missions. Boeing is pursuing follow-on research in these areas, according to Jose Enrique Roman, director of engineering at Boeing Research and Engineering Europe.

Another quite unrelated application of hydrogen fuel cells also had a challenge in the air. Launched in 2001, Jadoo Power (Folsom, Calif.) makes portable fuel cell-powered systems for a variety of markets, including professional broadcast cameras, emergency response, law enforcement and the military.

But in the early years, the market for Jadoo's compact fuel cells was limited, because camera operators and other users could not transport them by plane. The company got its big break in 2004 when the U.S. Department of Transportation approved Jadoo's N-Stor fuel canister for transport in air cargo, the first approval of its kind.

Since then, Jadoo, which means "magic" in Hindu, has established itself as a leader in the portable PEM fuel cell market. While the environmental advantages of fuel cells are an important feature, the real selling point is in the size and weight of the units, according to Leonard Devanna, Jadoo's CEO.

Take, for instance, a military field radio that Jadoo is working on now called the Delta II, which weighs in at 18 pounds. For a mission lasting 11 days, the previous generation radio relied on batteries that weighed 79 pounds. The lighter, more compact Jadoo fuel cells would eliminate 61 pounds from the weight of the radio carried by a soldier. And the Delta II cuts the cost per watt by more than half, compared with the alternate, according to Devanna.

The technology has a few more hurdles to jump before Jadoo's hydrogen fuel cells will be on the shelves at The Home Depot, said Devanna. Most important, federal and state governments need to develop regulations and standards for hydrogen canisters and replacement cells. That's a big hurdle.

What's Devanna's estimated time of arrival for widespread adoption? "Three to four years," he said.

Making waves

According to a report by the U.S. Department of Interior, ocean currents represent a significant untapped reservoir of energy. Water is more than 800 times denser than wind, so for the same area of flow that is captured by a turbine, the energy contained in a 12-mile-per-hour water flow is equivalent to that contained in an air mass moving at about 110 mph.

This potential free power source has not been lost on Europeans, Australians and now a number of states within the United States, including Alaska, California, New York, Oregon and Washington. All have pilot wave or current programs either in place or planned within the next few years.

One example is in the East River that runs between Manhattan and Queens in New York, near Roosevelt Island. Verdant Power (New York) has been operating a pilot program here since 2006 called the Roosevelt Island Tidal Energy (RITE) Project. Verdant has harnessed the strong tidal current with six 16-foot turbines attached to the floor of the river 30 feet below the surface.

As part of the RITE project last year, the turbines were tapped to power a grocery store and a parking garage on Roosevelt Island. The plan now is to build out the turbine farm, which the company estimates will produce 10 MW of power.

Recently, the government of Ontario funded a project to assess generating power from the current in the St. Lawrence River. Verdant is installing turbines as part of this project.

And earlier this year on the West Cost, California's Power, Gas and Electric (PG&E) announced it will be engaging in a 15-year power purchase agreement with Finavera Renewables Inc., a Vancouver, B.C.- based company that captures the power of wave

energy. The company plans to create a modest wave park of power-generating buoys a few miles off the coast of Humboldt County in northern California.

This is the first U.S. utility company that has committed to purchasing wave power. The project is expected to be attached to the grid by 2010.

According to the Electric Power Research Institute (Palo Alto, Calif.), there is approximately 8,000 MW of wave power energy that could be captured off the California coastline.

Of course, not everyone is happy about tapping wave power. Fishermen are concerned about access to fishing grounds and, ironically, environmentalists worry about underwater habitats.