

Renewable Energy: Opportunities for Cryogenics and SC

As the Western world faces escalating prices for oil and natural gas, heavy dependence on foreign sources, and the challenges of global warming, many nations are engaged in an all-out effort to find renewable energy sources.

Renewable energy makes use of resources that are replenished naturally, and includes solar power, wind power, hydroelectricity, micro hydro, biomass and biofuels. As new technology is being developed to make use of these resources, new opportunities are coming forward in the fields of cryogenics and superconductivity, whose technology can increase the efficiency of these new energy-harnessing options.

Many nations are starting to seek alternative ways of producing electricity. Leaders in European countries are especially committed to working towards finding new sources of energy. In March 2007, the European Union announced plans to work toward a 20% boost in overall renewable fuel use by 2020. The plan involves a commitment

to increase the use of solar, wind and hydroelectric power. In the United States, too, there has been a recent push towards pursuing renewable energy sources as a way to keep up with increasing demand for electricity.

Wind Power

Wind power has a number of benefits. Harnessing this clean, free energy source reduces air pollution, helps cut back on imported fuels, creates jobs and provides energy security. The Global Wind Energy Council has identified wind power as a "mature and booming global business," with generation costs decreased by 50% over the last 15 years. Currently, the European Union is the world's strongest market for wind energy.

The Council states that wind power is the leading renewable energy source in Germany, which leads the way in turbine manufacture. Part of the impetus for this move toward renewable energy is the desire to reduce the country's

heavy dependence on foreign sources of energy.

According to the WorldWatch Institute, Germany's Ministry for the Environment, Nature Conservation and Nuclear Safety reported that more than 9 billion euros (US\$12.7 billion) was invested in renewable energy installations in Germany in 2006, with approximately 240,000 people employed in the renewable energy sector in the same year—a 40% increase over 2004. There were a number of economic benefits reported, including fuel-import savings of 0.9 euro (\$1.27 billion).

The United States has also seen a dramatic increase in the annual market for wind power over the last few years. A number of new wind power projects currently in the works exemplify this growth. According to the National Renewable Energy Laboratory (NREL), a new wind turbine test facility will be constructed in Ingleside TX and there are plans to build a new R&D facility in Boulder CO.

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"The US wind industry grew by an astounding 45 percent in 2007," said NREL Director Dan Arvizu. "These projects demonstrate a commitment to the crucial technology R&D—and the public-private partnerships—that will be necessary to ensure the wind power industry's continued momentum."

Other major players within the US energy industry are taking note of the potential for wind energy. According to CNET news, oil mogul T. Boone Pickens has launched a campaign for his "Pickens Plan," which would make use of wind power in the Midwest to replace the natural gas currently being used to supply electricity. The natural gas would instead be used as transportation fuel.

A similar plan was announced by the US Department of Energy in 2008. A report entitled "20% Wind Energy by 2030: Increasing Wind Energy's Contribution to US Electricity Supply,"

details the costs, challenges and the overall impact that the "20% Wind Scenario" would have on the nation's energy portfolio.

One of the aims of this plan is to reduce the reliance on foreign sources of natural gas using wind power, which could be accomplished through existing resources and technology. New wind power installations would have to increase to more than 16,000 MW per year, and continue that trend until 2030. According to the report, the wind industry could accomplish the following in the decade before 2030:

- Support roughly 500,000 jobs in the US, with an annual average of more than 150,000 workers directly involved in the wind industry;

- Support more than 100,000 jobs in associated industries (e.g., accountants, lawyers, steel workers, and electrical manufacturing);

- Support more than 200,000 jobs through economic expansion based on local spending;

- Increase annual property tax revenues to more than \$1.5 billion by 2030; and

- Increase annual payments to rural landowners to more than \$600 million in 2030.

Wave Power

Wave power, another emerging renewable energy source, has also shown great potential for inclusion in the nation's energy portfolio. According to the National Science Foundation, wave power is a "promising, clean energy source that is more predictable, available and energy-dense than wind is." The linear up-and-down motion of ocean waves is converted into electricity, and this energy is harnessed through buoy systems where electric coils surround a magnetic shaft inside of a buoy.

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This magnetic shaft is anchored to the seafloor. Hence, these linear generator buoys make use of the ocean's waves to induce voltage.

Opportunities for Cryogenics and Superconductivity

With such potential for renewable energy sources, new opportunities for applying existing technologies to harnessing energy are being developed. High temperature superconducting technologies can be employed in both wind power systems and ocean buoy systems, allowing for a number of advantages over conventional technology.

Wind Power: Zenergy and Converteam

In the coming year, Zenergy Power, Inc. will work with Converteam to develop a subscale wind generator based on a full-scale 8MW design. Zenergy will supply the HTS coils for Converteam's wind generator, and the companies expect to demonstrate a full-scale generator in 2011 and a commercial-scale version by 2012.

While conventional wind generators have gotten much bigger in size recently, this generator, employing HTS technology, will have a 66% reduced size and 75% reduced mass compared to conventional systems of similar production capacity, according to Zenergy. Other benefits are high productivity, less maintenance expenditure and better cost economy in operation.

Wind Power: AMSC and TECO-Westinghouse

American Superconductor and TECO-Westinghouse have formed a research joint-venture to develop HTS technology for 10 MW-class HTS direct drive wind generators, which will be smaller, lighter and more efficient than conventional generators. The National Institute of Standards and Technology will provide \$3.4 million to the \$6.8 million research project.

"Wind turbine generators (asynchronous and induction) are typically hooked up to gearboxes to turn the rotor's slow speed, high torque motion into the high speed, low torque motion needed for induction and synchronous generators," said Jason Fredette, Director of Investor and Media Relations at American Superconductor. "By producing a direct drive generator, we are negating the need for a wind turbine gearbox, which further reduces weight and enhances reliability."

These companies are demonstrating the ability of HTS to improve on wind generator technology, ensuring that as the renewable energy market grows, the demand will be met with newer, more efficient equipment.

Wave Power: Converteam and OPT

While wind power technologies continue to improve, some companies are developing ways of applying HTS technology to other renewable energy sources, such as wave power. Converteam is working with Ocean Power Technologies to supply HTS linear generators for use in OPT's PowerBuoy® wave energy converters. Converteam's Technology Director Derek Grieve said, "HTS offers a linear generator of unprecedented power density and efficiency enabling significantly more energy to be converted to electrical power. Converteam already has ongoing HTS projects in hydro, marine and wind. These are all migrating to second generation HTS wire which has a much higher flux density, lower cost and operates at higher temperatures than first generation wires, allowing the use of a cheap coolant medium."

Future Challenges

Both wind power and wave power projects have shown the potential for cryocooler manufacturers and HTS technology experts to contribute to advances in renewable energy. "These are applications that really need HTS and cryo-refrigerators," said a source in the cryo-refrigeration industry. "Cryo-refrigeration has served a lot of technological needs in the past, and now we're looking at opportunities for cryogenics in the energy business—one of the biggest markets in the world."

But in a recent interview with *Cold Facts* magazine, Dr. Larry Masur, Zenergy's Vice President, Business Development, commented on the fact that there are still challenges to overcome when it comes to designing cryogenic equipment for these specific applications.

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Cryogenic Concepts

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This column is prompted by a very excited phone call from a client a few weeks ago. Part of his business involves removing formed rubber or dense foam liners from 6- to 8-inch heavy-walled pipes which house spiral rotors used to pump oil field “mud.” The liners wear out on a regular basis and are routinely replaced by new ones.

Removing the worn liners is not an easy task. The bonding agent between the elastomers and pipes is strong and tough. It must survive high temperature ambients and winter use in sub-arctic northern climes. The most effective method is to position a batch of 20-foot-long pipes in an insulated chamber and sprinkle liquid nitrogen along their lengths until the outer surface temperatures approach 100K. After a cold soak period, this is sufficient to fracture the bond between each pipe and its elastomer liner. Once the bond is broken, the liner can be pushed out in one piece. This can be done warm or cold but it saves time to remove the pipes from the chamber and push the liners out while they are still quite cold.

On the day of the excitement, the pipe in question may have been cooled down to nearly 78K. It was removed from the chamber and clamped into the holding fixture to allow the hydraulic ram to push out the liner. After pushing about two

feet, there was a “pop” and a flash of fire past the ram and out the open end of the pipe. Fortunately, no one was hurt and there was no damage to the pipe or equipment.

What happened? As soon as the pipe was removed from the cold chamber, ambient air was cryopumped into the annular crack between the pipe ID and somewhat shrunken elastomer liner. The very cold pipe preferably condensed some of the oxygen in the air that was drawn in. Then, as the pipe warmed up, the oxygen vaporized to create an oxygen-rich mixture. Friction heating of the liner being pushed out was sufficient to ignite and burn the elastomer at an accelerated rate. (The recommended solution to this particular problem was to not cool the pipe colder than 100K.)

This is not an isolated case. Paragraph 6.7.4.2.6 of the current ADR Volume II states: “Portable tanks intended for transport of refrigerated liquefied gases having a boiling point below -182 deg C at atmospheric pressure shall not include materials which may react with oxygen or oxygen-enriched atmospheres in a dangerous manner when located in part of thermal insulation when there is a risk of contact with oxygen or with enriched oxygen fluid.”

The practical impact of this rule is that international transport dewars for oxygen and colder cryogenics may not have flammable insulation. This specifically rules out use of aluminumized Mylar® in multilayer insulation (MLI).

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He says that existing technology “must be manufactured with enough volume and standardization to lower manufacturing costs and hence price. In addition, the cooler technology needs to be adapted to harsh environments like industrial factories and offshore settings.”

Masur also points out that without adequate funding from the US Department of Energy, there will be major roadblocks in achieving the necessary milestones that will allow HTS technology to flourish in renewable energy projects.

“The US DOE superconductivity budget should be returned to the levels of a few years ago. The additional resource would accelerate the timeline for development and adoption of HTS

equipment,” said Masur.

There are also challenges when it comes to the superconducting wire that enables these technologies. A June 2007 report from Clive Lewis and Jens Müller of Converteam mentions that in order for the production of an HTS wind generator to be successful, HTS wire must be manufactured in volume at low cost.

Second-generation, or 2G wire, would need to have a large enough demand that costs are brought under control. Unlike 1G wire, which was largely bismuth-based, 2G wire is a newer, yttrium-based option that operates at higher temperatures with superior performance in a magnetic field.

Also, this wire carries a projected lower cost than 1G wire and is available

in sufficient quantities. But the cost must decrease even more for the 2G wire to be widely available for use in developing technologies.

In a recent interview with *Cold Facts* magazine, Dr. Venkat Selvamanickam of Superpower expressed his confidence in the company’s progress toward this goal.

“I think Superpower and others have clearly demonstrated that 2G HTS wire is something that can be made into devices that can be tested and successfully operated and can demonstrate important benefits over conventional technology. I think we have overcome most of the technical barriers, and we just need to take the final few steps.”

