RENEWABLES: FUTURE SHOCK

The National Renewable Energy Laboratory is developing technologies well on their way to becoming competitive with oil and gas.

ARTICLE BY
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The company in the early 1900s that thought it was in the trolley-car business instead of the transportation business isn't around anymore. And the independent producer or refiner in the early 2000s that thinks it's in the oil and gas business instead of the energy business is also doomed to eventual extinction.

This is the message Shell Oil Co. conveyed to its new employees as far back as the mid-1960s, and it's one that's still valid today. In short, the future belongs to those in the oil patch who recognize that the flow of nonrenewable resources such as oil and gas will inevitably slow to a trickle—between 2025 and 2050, or shortly thereafter—and that now is the time to be focusing on alternative, renewable forms of energy.

At the National Renewable Energy Laboratory (NREL) in Golden, Colorado, that's precisely what's being researched and developed—particularly energy from photovoltaics, biomass and wind turbines.

The lab, originally established by the Department of Energy in 1977 as the Solar Energy Research Institute, is managed and operated under contract to the DOE by the Midwest Research Institute, based in Kansas City, Missouri; the Battelle Memorial Institute, headquartered in Columbus, Ohio; and Bechtel Corp., the San Francisco-based international engineering and construction firm.

With current annual funding of about $200 million, the mission of the 1,100-member staff of the campus is to develop renewable energy and energy-efficient technologies, in partnership with private industry and universities throughout the country, says Robert J. Noun, NREL director of public affairs. While this includes a focus on advanced vehicle technologies such as hybrid gasoline-electric cars, and devising ways to make buildings more energy efficient, 70% of the research work is geared to advancing the supply-side energy technologies of photovoltaics, biomass and wind.

To think for a moment these technologies are embryonic pipe dreams decades away from practical application would be akin to believing at the start of the 1960s that the U.S. wouldn't put a man on the moon.

"True, in the 1970s, we were doing mostly basic research on these technologies," says Noun. "But now we're at the point of moving these technologies into the marketplace, so feasibility is no longer an issue. What is an issue is

Photovoltaic devices are used on the 800-mile-long Trans-Alaska Pipeline to provide cathodic protection for the giant oil pipeline. When voltage is applied to the line, corrosion can't build up, explains Lawrence L. Kazmerski, director of NREL's National Center for Photovoltaics.

Stanley R. Bull, associate director of Science and Technology for NREL, notes that Washington Water Power Co. in Kettle Falls, Washington, uses biomass in its wood-burning plant (at right) to generate cost-effective electricity.

bringing down the costs of these technologies—by reducing the manufacturing costs associated with them and improving their efficiencies."

Seeing the light

Take photovoltaic (PV) devices, commonly called solar cells or modules, which use semiconductor material to directly convert sunlight into electricity. "These devices aren't five or 10 years away—today, they comprise a very real and profitable business worldwide," says Lawrence L. Kazmerski, director of NREL's National Center for Photovoltaics at Golden. "In fact, most photovoltaic companies are 12 to 18 months back-ordered on their product—and they're facing growing demand."

Indeed, photovoltaic devices are used to power remote residences, satellites, highway emergency-call boxes, highway-information signs, water pumps, streetlights and calculators. They're also used by electric utilities to provide power to customers. And the oil and gas industry uses them to power communications equipment on offshore rigs or platforms, well-control and monitoring systems in remote locations, and to provide cathodic protection to millions of miles of pipelines. In the latter case, when voltage is applied to a pipeline, corrosion can't build up on the line.

Currently, about 85% of commercially available photovoltaic modules are made from crystalline silicon cells similar to those found on computer chips. The other 15% use newer, thin-film technology, whereby very thin layers of semiconductor material are deposited on glass or thin metal mechanically supporting the cell or module. While not as efficient as crystalline silicon cells, thin-film photovoltaic cells—the wave of the future in PV technology—use up to 100 times less semiconductor material and are easier and less expensive to manufacture.

"Some 35 years ago, when I started in photovoltaics, these devices were used almost exclusively for satellites. A solar cell would cost about $300 to $600 per watt," says Kazmerski. "Today, a solar-cell module—such as you would put on your roof—costs $3 to $6 per watt. And in the future, with the use of thin-film PV technology, we could see that cost drop by half. In addition, the efficiency of commercial solar cells—their ability to convert sunlight into electricity—has risen from 7% to about 15% to 18%."

How big is this industry? Right now, the U.S. photovoltaics business is around $800- to $900 million a year, he says; worldwide, it's about $2 billion. By 2020, it's expected to grow to $15 billion in the U.S. alone, and by 2025, to $30- to $40 billion worldwide.

"We're already seeing huge PV demand in Japan and Germany, mainly for residences and commercial buildings tied directly into electric utility grids," says Kazmerski. "In this country, California is providing tax incentives for homeowners to install photovoltaic-moduled roofing. During the day, these homes can sell the PV-generated power they don't need—to the grid for a utility's peak-load periods—then buy it back when needed at night. Such a distributed-power system saves the utility the cost of adding as many more plants to meet demand, and it saves the homeowner money."

By 2030, it's anticipated photovoltaic electricity will account for at least 10% of U.S. peak power-generation capacity—the energy equivalent of 180 million barrels of oil. The Japanese and the Europeans are a little more aggressive—they see this market approaching 20% worldwide.

Among the key industry players in photovoltaics are Shell and BP, says Kazmerski. "To their credit, they see PV as a complement to conventional fossil fuels and a resource that will have a big role in meeting future energy demands in certain areas. Putting its money where its analysis is, Shell Solar is not only building its own photovoltaic power plants, especially in Europe, but also has a joint-venture investment in this technology with Siemens Solar Industries in California."

Kazmerski praises BP Solar for seeing the light in this renewable energy resource. "Currently, Siemens and Shell Solar have a bit more than 20% of the PV market worldwide; BP Solar and AstroPower, a rising U.S. company, another 30%; and Japanese, European and newer, thin-film manufacturers worldwide, nearly 50%."

He looks to the future integration of thin-film PV technology into glass skyscrapers. "This technology won't simply be applied to a window pane—it will *be* the window pane." When this technology is developed, all the suitable window space in the U.S. will be more than sufficient to generate from one-third to perhaps all the electricity needed in this country, he predicts.

Waste-to-energy

Another renewable resource NREL is researching is biomass energy—for electricity generation, home heating, fueling vehicles and providing process heat for industrial facilities. The majority of this energy is produced from wood and wood wastes (64%), municipal solid waste (24%), agricultural waste (5%) and landfill gases (5%). Dedicated energy crops, including fast-growing grasses like switch grass, which grows six feet tall in a year, and fast-growing trees like poplar—grown specifically for energy production—are also expected to make a significant contribution in the future.

"We started out looking at biomass principally for transportation fuels; since 1990, we've begun to emphasize not only biomass fuels but biomass electricity," says Stanley R. Bull, associate director of Science and Technology for all of NREL, including biomass research. "In the future, we'll emphasize multiproducts from biomass refineries that are still in the planning stage."

There are several ways to produce electricity from biomass. One is to simply burn it, which produces steam that turns a turbine, generating electricity. "That's the predominant way biomass is used today to generate electricity—notably in the forest-products industry, where abundant waste wood is burned for that purpose." Also, biomass is being used heavily for electric generation in California, where various waste products provide the feedstock. With this approach, 25% to 35% of the biomass is converted to electricity.

"We're also starting to co-fire biomass with coal," says Bull. "That has the benefit of using more biomass while reducing nitrogen oxide and sulfur emissions from a coal plant. But there are more efficient ways to use biomass for electric generation. One advanced approach is to gasify biomass."

Through this process, high temperatures reduce biomass into simpler elements, and the gas from this fires an electricity-generation turbine. "Using this approach, you can get higher [biomass conversion-to-electricity] efficiencies—around 40% or better."

In cooperation with Burlington Electric, NREL is using this technique in a 50,000-megawatt plant in Burlington, Vermont, where some 200 tons a day of biomass are being gasified to supplement the plant's electric generation. Nationwide, an estimated 7,500 megawatts of power are being produced from biomass.

Biomass electricity can be competitive, he says: In 1980, electricity generated this way cost 12 cents per kilowatt hour; today, costs are 6 to 7 cents.

The cost of producing transportation fuels from biomass has also fallen as the result of NREL's research. "Most of our emphasis during the past 20 years has been on producing ethanol from biomass such as corn stalk or corn stover." This is not the ethanol from the grain part of the corn that's so widely sold at service stations across the country and is being produced at the rate of 2 billion gallons per year.

"Back in 1980, we projected that corn stover-based ethanol from a plant built then would cost about \$3.60 to \$3.80 per gallon; now, we estimate \$1.22 per gallon. And by 2010—when some of these ethanol plants come off the drawing boards and are actually built—the cost of a gallon of ethanol from biomass could drop to 67 cents."

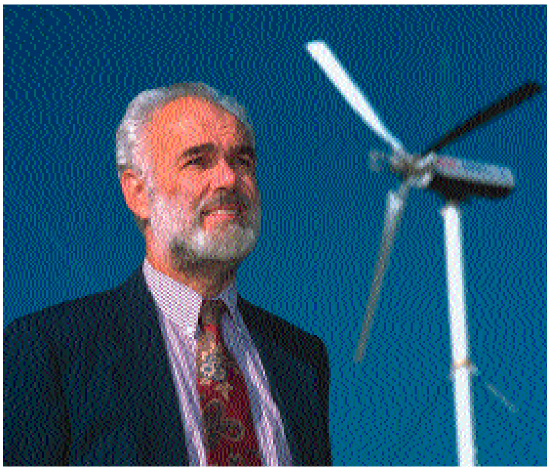
This cost could be even lower if NREL's vision of building biomass refineries—along the lines of petroleum refineries—bears fruition. "By producing not one, but a slate of products from biomass—including ethanol, chemicals, feedstocks for plastics, charcoal, fertilizers and electricity—the economics of biomass could be enhanced dramatically," says Bull.

"During the next 10 years, this is the earliest and best opportunity for biomass to make a significant impact in the energy arena. Currently, biomass contributes 3% to total U.S. energy supply, but by 2010 it should make up 6% of overall domestic energy output. And if these bio-refineries come online, that contribution could rise by multiples after 2010."

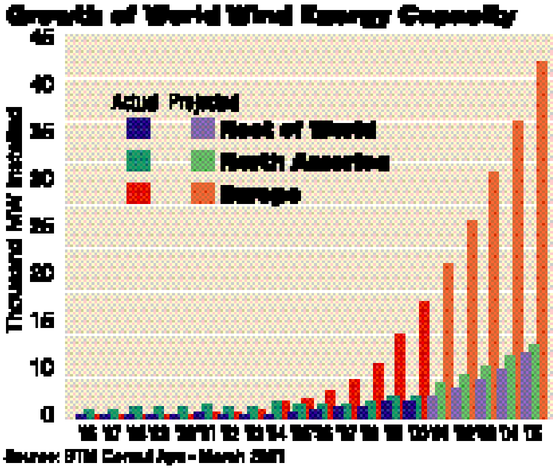
Harnessing the wind

Housed on a sprawling 280-acre site just north of Golden is another research pioneer—Robert W. Thresher, director of NREL's National Wind Technology Center. He started working in wind energy in 1973, right after the first oil embargo.

"Wind technology goes all the way back to Persian times," he says "Sails were put on wooden poles, causing them to turn a pump and lift water from river banks. Then, with the advent of electricity in the last century, people in the 1920s came up with small-diameter wind turbines—battery-charging devices that allowed them to listen to the radio or run a few lights."



Robert W. Thresher, director of NREL's National Wind Technology Center, says that over the past 15 years, the use of wind power has grown dramatically worldwide, particularly in Europe, and should continue to rise, as chart at right projects. By 2020, he expects 80,000 megawatts of wind power to be online in the U.S.—roughly 5% of total U.S. energy production by then.



Basically, the wind drove a propeller which drove a shaft and a gear box that increased the shaft's rotation speed. This, in turn, drove a generator which charged the battery.

With the abundance of oil and gas in the U.S., however, not much was done to develop wind turbines for use in an electric utility grid—until the 1970s. "In that decade, we saw the building of 100-kilowatt wind turbines all the way up to 2.5-megawatt wind machines with a 300-foot rotor diameter," says Thresher. "The only problem with them was that they cost about 40 cents per kilowatt hour to run—way too expensive to be economically viable."

But in the early 1980s, as these machines were being phased out, California established tax credits that made it profitable to build and sell wind power—even if electric companies only paid 10 cents per kilowatt hour. In this environment, companies like U.S. Wind Power Co., which then produced small, 50-kilowatt wind turbines, began popping up. With the fall in oil prices in the mid-1980s, wind power once again found itself disadvantaged in the market, with utilities only willing to pay 3 cents per kilowatt hour.

"Since then, wind machines have become bigger, more efficient and cost-effective; also, better siting by wind companies is allowing them to capture more wind for their capital equipment costs," says Thresher. Their costs have dropped to 4 to 5 cents per kilowatt hour. So now, between a tax subsidy in the U.S. of 1.7 to 1.8 cents per kilowatt hour and utility contracts of 3- to 4 cents per kilowatt hour, they're again able to be profitable.

No small role in making those wind turbines more efficient and cost-effective is being played by Thresher's group at NREL. "We've developed some new technologies here, including special air-foil shapes that make better use of the wind, reduce aerodynamic loads on the structures and improve their energy-capture efficiency. In addition, we're not only able to analyze large wind-turbine structures, but also we're an accredited laboratory. That means we can go beyond analysis and field-test these huge machines for such things as blade fatigue, gear-box durability and power performance." This helps the industry climb the learning curve, in terms of what needs to be done to produce a reliable wind structure. "Also, we sit on the international standards writing body for wind turbines."

Thresher stresses that, during the past 30 years, the industry has reduced costs from 40 cents per kilowatt hour to 4 to 5 cents. "Our vision is to take the cost of utility-scale, grid-connected wind power down to 3 cents per kilowatt hour—competitive with oil and gas, particularly gas—during the next 10 years."

By 2020, Thresher anticipates about 80,000 megawatts of wind power will be online in the U.S.—roughly 5% of total U.S. energy production by then. Currently, only 3,000 megawatts of wind power are online in the U.S.—about one-tenth of 1% of domestic installed electric-generating capacity. Comparatively, wind power accounts for about 17,000 megawatts of installed electric-generation capacity worldwide, mostly in Europe. Notably, wind power is about 13% of Denmark's total energy production and nearly 10% of Germany's.

Among big wind players in the U.S., Enron Wind Corp. tops the list. This year, the Enron Corp. subsidiary, with which NREL has a cost-shared development subcontract, will be selling 300 wind machines with 1.5-megawatt capacity, domestically. Additionally, Enron Wind has a sister wind company in Germany and another in Spain, through which it's making European sales.

Other players in the U.S. market include Wind Turbine Co. near Seattle; Clipper LLC, the wind turbine subsidiary of Santa Barbara-based Dehlsen & Associates; and Europe-based generator manufacturers ABB and Siemens. In addition, several Danish companies are setting up wind-machine assembly and manufacturing facilities in the U.S., including Micon USA in Indiana, and Vestas America in Colorado.

Says Thresher, "Wind power is *the* fastest growing electric-generation source in the world, with an average annual growth rate approaching 30%. Whether you're an energy company, an investor or a fabricator of some kind, this is a technology worth attention." □

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