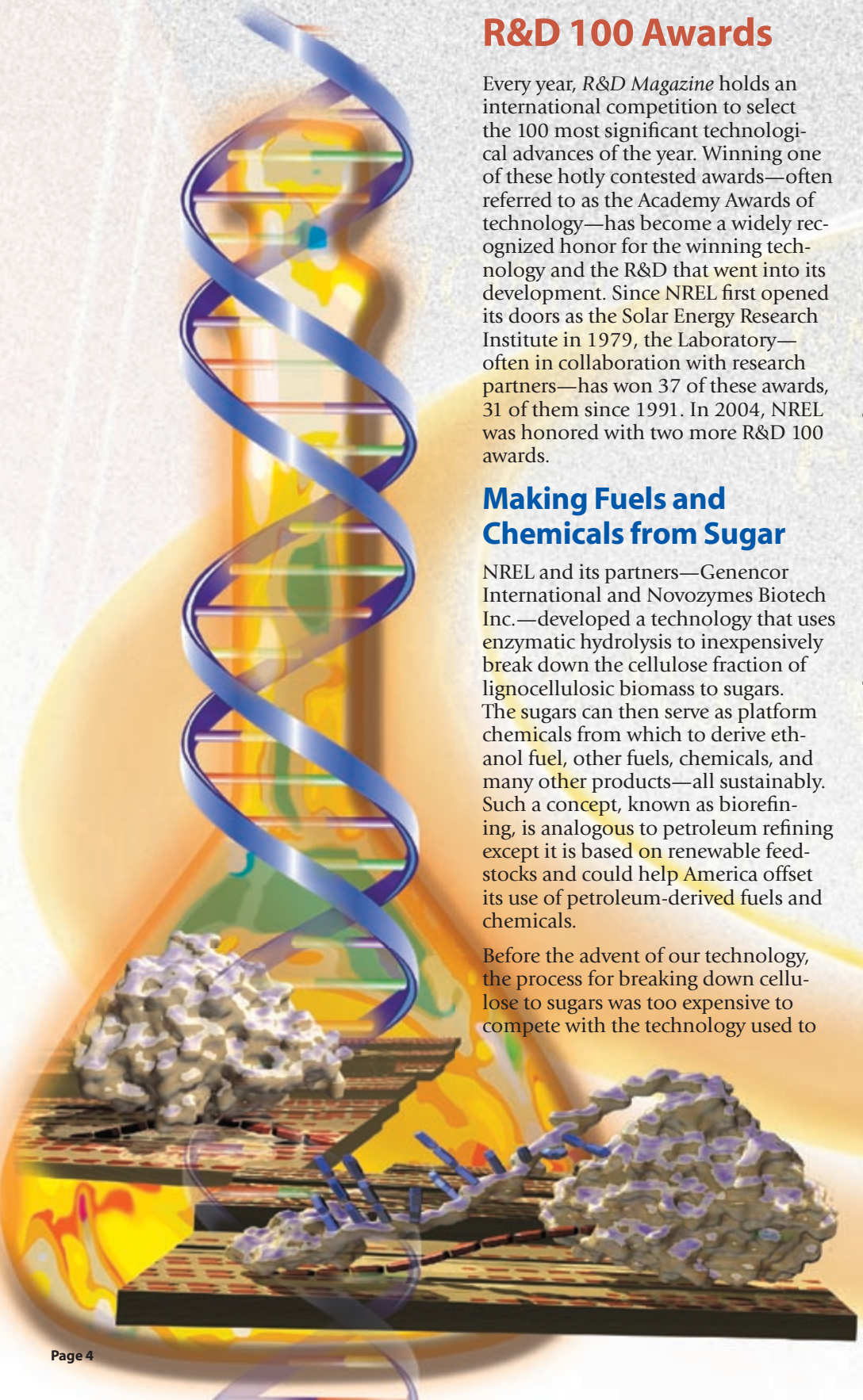
Awards & Honors



R&D 100 Awards

Every year, *R&D Magazine* holds an international competition to select the 100 most significant technological advances of the year. Winning one of these hotly contested awards—often referred to as the Academy Awards of technology—has become a widely recognized honor for the winning technology and the R&D that went into its development. Since NREL first opened its doors as the Solar Energy Research Institute in 1979, the Laboratory—often in collaboration with research partners—has won 37 of these awards, 31 of them since 1991. In 2004, NREL was honored with two more R&D 100 awards.

Making Fuels and Chemicals from Sugar

NREL and its partners—Genencor International and Novozymes Biotech Inc.—developed a technology that uses enzymatic hydrolysis to inexpensively break down the cellulose fraction of lignocellulosic biomass to sugars. The sugars can then serve as platform chemicals from which to derive ethanol fuel, other fuels, chemicals, and many other products—all sustainably. Such a concept, known as biorefining, is analogous to petroleum refining except it is based on renewable feedstocks and could help America offset its use of petroleum-derived fuels and chemicals.

Before the advent of our technology, the process for breaking down cellulose to sugars was too expensive to compete with the technology used to break down starch in corn kernels to sugars; or to compete with breaking down hydrocarbons in petroleum for the production of the fuels, chemicals, and products that help run our modern economy.

Lignocellulosic biomass consists of cellulose, hemicellulose, and lignin, with cellulose constituting up to 50% of the total mass. Like starch and sugar, hemicellulose and cellulose are carbohydrates (compounds of carbon, hydrogen, and oxygen). The sugars of which they are made are linked together in long chains called polysaccharides, which form the structural portion of plant cell walls. Unraveling these complex structures is the key to economic biorefining.

Cellulose microfibrils consist of a crystalline structure of thousands of strands, each of which contains hundreds of glucose sugar molecules. These microfibrils are wrapped in a sheath of hemicellulose and lignin, which protects the cellulose from microbial attack. Hemicellulose is relatively easy to break down into its component sugars using heat, pressure, and dilute acid. This "dilute acid hydrolysis" pretreatment step also disrupts the hemicellulose/lignin sheath around the cellulose, making the cellulose accessible to further hydrolysis.

To hydrolyze the cellulose, NREL and its partners developed a technology that employs a cocktail of three types of cellulase enzymes—endoglucanase, exoglucanase, and betaglucosidase. In consort, these enzymes break cellulose chains in two, exposing the ends of the chains, and then break down these chains into units of cellobiose (a dimeric sugar comprised of two

glucose molecules). They then split the cellobiose molecule into two separate glucose molecules, making them available for processing into fuels or chemicals.

Until the advent of our breakthrough technology, other methods of hydrolyzing cellulose to sugars—including strong acid hydrolysis and older versions of enzymatic hydrolysis—were inefficient, expensive, and had low sugar yields. Enzymatic hydrolysis was also too expensive, but it had great potential. The strategy to take advantage of this potential was twofold: improve the pretreatment (i.e., the dilute acid hydrolysis) process and reduce the cost of the enzymes. Reducing the cost of the enzymes also followed a twofold strategy: engineer better enzymes, so that less enzyme is needed per gallon unit of sugar output; and optimize the enzyme-production system. The task of improving the pretreatment fell to NREL, while reducing the cost of the enzymes became the task of Genencor and Novozymes (working separately on their respective proprietary strains to produce more efficient cellulase systems and to improve the economics of their proprietary production methods). NREL also validated and verified technical improvements at each stage of development.

As a result, NREL and its partners developed a technology that is efficient, has high sugar yields, and has already dropped the cost of cellulose hydrolysis by 20-fold. Moreover, this technology holds the promise of decreasing the cost by as much as another order of magnitude, and maybe more.

One of the reasons for developing this technology is to produce inexpensive ethanol fuel from lignocellulosic biomass. The United States has enough of this resource to sustainably make as much as 30 to 45 billion gallons of ethanol per year. This would not only significantly offset the nation's consumption of gasoline (which stands at about 135 billion gallons today), but it would also lead to large offsets of greenhouse-gas emissions as the ethanol displaces our use of petroleum. Ethanol derived from lignocellulosic biomass can use the lignin portion to produce the heat and electricity required to run the process to make it. The use of lignin thus offsets energy that would otherwise be conventionally obtained from fossil fuels. This, along with the fact that burning ethanol produces less net CO_2 emissions as a result of re-assimilation of CO_2 into plant matter via the carbon cycle (growing biomass absorbs CO_2), enables the entire "plant to wheels" process of lignocellulosic production of fuel ethanol to actually have negative greenhouse gas emissions relative to the "oil well to wheels" process for gasoline. The end result is a net offset of up to 600 g of CO_2 per mile when lignocellulosic ethanol is used for transportation in place of petroleum.

But producing ethanol fuel is just the beginning. Using different microbes and processing techniques, we can build biorefineries with which to derive many other products, including plastics, fibers, textiles, polymers, films, lubricants, adhesives, cements, solvents, chemical intermediates, photographic chemicals, cleaning agents, coatings and paints, fillers and insulation, cosmetics and personal-care products, pharmaceuticals and medical and dental products, other alcohols, antifreeze, softening agents, sweeteners, dyes and perfumes, insecticides, food additives, and much more. Our technology, therefore, could help biorefineries begin to play a major role in America's economy.

Portable Solar Electricity

Thanks to Global Solar and its partners at ITN Energy Systems and NREL, the world now has its first portable, flexible PV systems made from copper indium gallium selenide (CIGS)—for use in mobile applications. These PV systems can provide from 12 W to 56 W of power, be folded into sizes as small as a 9 x 12 envelope, and be easily stowed in a small backpack. In addition, they are light enough to be carried over long distances, and can be connected together, when needed, to provide as much as 2.8 kW of power. One line of products using this technology is flexible enough to be rolled up to a size comparable to modern, lightweight, self-inflating mattresses used in backpacking.

The U.S. Army is already using these new systems in applications where both weight and space are at a premium—such as for scouts, forward field officers, special operations units, and forward communication units. For the military, the flexible CIGS modules can also provide portable power in the field without the drawback of the heat signature of diesel or gasoline generators.

Many of the features that make this technology so attractive to the military also make it appealing to a wide range of other applications. This

NREL researchers (left) collaborated with researchers from Genencor International (middle) and Novozymes Biotech Inc. (right) to develop an award-winning technology that enzymatically reduces cellulose to sugars. Only a few members and leaders of these large research teams are present in the photos.

CIGS technology can provide reliable power for hikers, campers, and boaters; police; portable electronics, such as cell phones, satellite phones, GPS units, computers, radios, and MP3 players; survival kits; battery chargers; and more.

The CIGS systems are not the first portable PV systems available. Systems based on amorphous silicon technology have been on the market for a few years. But the new CIGS portable PV technology has many advantages over these systems. Compared to them, for example, the CIGS systems:

- Are lighter, more flexible, and portable
- Are more efficient and reliable
- Have two to three times the power-to-weight ratio
- Have more than five times the power-to-volume ratio
- Cost less
- Are inherently self-repairing due to the natural tendency of copper atoms in the CIGS material to spread into damaged areas, thereby repairing the crystal structure. In fact, CIGS modules can even take a bullet hole and continue to operate.

Another advantage of the CIGS technology is that it is extremely versatile. Modules can be fabricated on a variety of substrates—flexible, rigid, or substrates that can conform to many surfaces. As such, the CIGS systems can be included on all kinds of structures such as signs, bus shelters, sun roofs, or awnings; or they can be integrated into building applications and be used on metal roofs, as roof shingles, or in architectural fabrics or facades.

From 1994 through 2004 worldwide PV module sales increased more than 15-fold—from less than 70 MW per year to more than 1.1 GW per year. And the annual market for the sale and installation of PV systems is fast approaching $10 billion. The great majority of this market belongs to silicon PV technology, especially crystalline silicon. The advent of flexible CIGS technology is significant for at least two reasons. First, this technology is opening up a whole new category of applications for photovoltaics. Second, but equally important is the arrival of this valuable thin-film material on the commercial scene. It has a great potential, especially as it gains a larger share of the market, to reduce the cost of PV electricity and thus augment the phenomenal growth of the PV market.

Other Awards & Honors

Technology Transfer Awards

NREL was honored with three awards from the Mid-Continent Region of the Federal Laboratory Consortium (FLC) for Technology Transfer. The awards were presented at a September banquet on South Padre Island, Texas.

Two of the awards were for Notable Technology Development. The first of these recognized the work that the Vehicle Ancillary Loads Reduction Team performed for the Thermal Comfort Project. Team members Rob Farrington, John Rugh, Jason Lustbader, and Charlie King developed tools to analyze and improve the efficiency of climate control in vehicles. Their work has resulted in the development of the ADvanced Automotive Manikin (ADAM), the world's most advanced thermal comfort manikin. Using computer models that simulate human physical and psychological responses, it mimics human responses such as sweating and breathing. ADAM is designed not only to determine how hot or cold an occupant is, but also to predict how the occupant will feel.

The second award recognized the Advanced Petroleum-Based Fuels (APBF) Project, whose team members include Wendy Clark, Shawn Whitacre, Theresa Alleman, and Matt Thornton. The award commended their efforts in forming industrial partnerships, with the ultimate aim of reducing transportation-related petrochemical use and emissions. Project partners include vehicle manufacturers, equipment suppliers, and fuel providers. The APBF team brings value in the form of state-of-the-art laboratories and research, and patented technologies available for licensing.

Both projects are managed by the Laboratory's Center for Transportation Technologies and Systems.

Also honored by the FLC was Lawrence "Marty" Murphy, manager of NREL's Enterprise Development Programs. Murphy received a Distinguished Service Award for his leadership during the past nine years in building and promoting NREL's Enterprise Development Program and Industry Growth Venture Forums, which encourage the creation and growth of clean, efficient, and renewable energy companies. In the past few years, these activities have resulted in at least $5 million in private capital and $5 million in state and local funds for clean-energy commercialization, and more than 1,000 jobs created in successful clean-energy companies.

A Global Solar team (right), worked with teams from NREL (left) and ITN Energy Systems to develop lightweight, flexible, portable PV modules (above).

Steve Kelley Elected IAWS Fellow

In recognition of his valuable contributions to the fields of wood chemistry and technology, Principal Scientist Steve Kelley was elected a fellow of the International Academy of Wood Science (IAWS).

Since he joined NREL in 1992, Kelley's research has primarily focused on two areas: developing value-added products from biomass, and applying novel analytical tools for characterizing biomass and natural polymers.

Kelley has worked on developing phenolic resins from wood and bark, to replace petrochemical adhesives used to make wood products such as plywood. He has also worked to develop technology for making chemicals, monomers, and plastics from biomass rather than from petrochemicals.

"Cellulose, hemicellulose, and lignin in biomass are polymers to begin with," Kelley explains. "In the biorefinery approach that NREL is developing, we use chemical or biological techniques to break down the polymers to building blocks that can be refined and used for value-added applications. We have also looked at isolating and using the polymers in their original form."

Kelley was a key player in developing NREL's rapid biomass analysis technology, for which he and fellow researchers earned a prestigious R&D 100 Award in 2000. Combining near-infrared spectrometry with sophisticated multivariate analysis, the technology allows virtually instantaneous, nondestructive analysis of biomass, eliminating the need for expensive laboratory analysis that might take weeks. Kelley has taken this technology beyond its initial application for chemical analysis, extending its capabilities to determine mechanical properties and wood decay, and to evaluate wood composites. For example, it can be used to assess the dry strength of lumber that could be made from a tree while the tree is still standing in the forest.

Kelley has been the NREL lead on a series of projects designed to demonstrate the utility of these rapid analysis tools for understanding the effects of process variables on the chemical and physical properties of bio-based materials. He holds a B.S. in wood science from Oregon State University; an M.S. in forestry and wood science from the University of Wisconsin, Madison; and a Ph.D. in polymer chemistry from Virginia Tech. He has co-authored 65 publications and has 15 patents and submitted applications.

Women in Solar Energy Award

Cecile Warner, an NREL staff member for more than 25 years, received the 2004 Women in Solar Energy Award from the American Solar Energy Society. She was praised for outstanding and sustained contributions to solar photovoltaics, particularly for her public outreach efforts.

Cecile Warner stands on the mall in the nation's capitol, where crowds of people flock to see solar-powered homes designed by teams of college students for the U.S. Solar Decathlon.

In 2002, Warner led the Laboratory in developing and managing the highly acclaimed U.S. Solar Decathlon for the U.S. Department of Energy. The Solar Decathlon is a competition in which teams of college and university students compete to design the most attractive, effective, and efficient solar-powered house. She also served as director of the Laboratory's Center for Renewable Energy Resources from 1996–2000; and was project director of Sunrayce 93, a university competition of solar cars. Warner was elected to the Board of Directors of the American Solar Energy Society in 2000. She holds a B.S. and M.S. in mechanical engineering.

Truly Receives Energy Secretary's Gold Award

Former Secretary of Energy Spencer Abraham presented the Secretary's Gold Award to NREL Director Richard Truly and seven other current and former directors of DOE national laboratories. The award is DOE's highest honorary award and includes a plaque with citation, a medallion, and a rosette.

"I'm proud to recognize the people whose hard work and dedication contribute so much to the Department of Energy's vital missions," Abraham said. "Our world-class laboratories are a marvelous resource and have made far-reaching contributions—not only to the Department of Energy, but to our nation and, indeed, the world. The incredible work done in the laboratories is made possible by the strong, steady, and responsible leadership of these directors."

Truly was recognized for his superior leadership as director of NREL and for his vision and perseverance in helping transform NREL into the premier national institution in its field.

Secretary Abraham presented the awards at an October 25 luncheon at the Woodrow Wilson International Center for Scholars in Washington, D.C.

The Secretary's Gold Award plaque was presented to NREL director Richard Truly by former DOE Secretary Spencer Abraham.