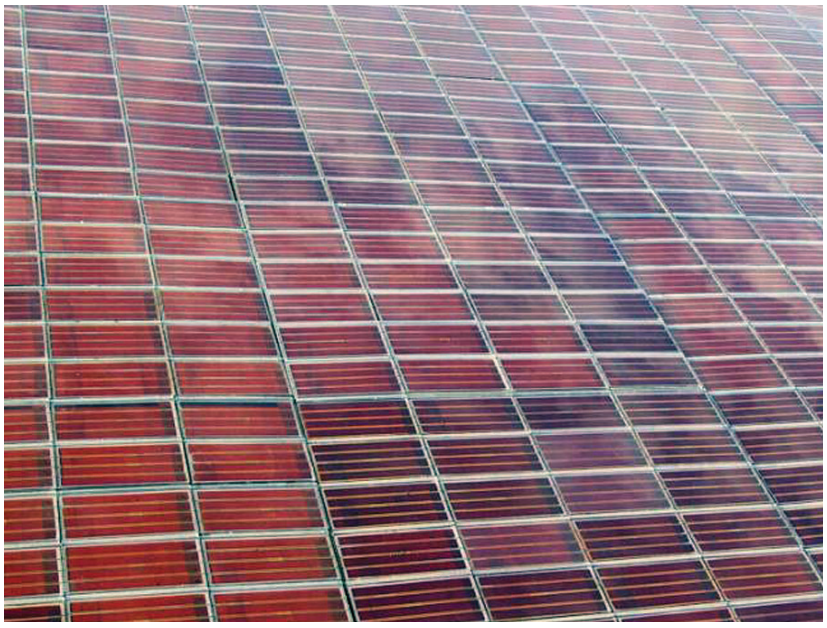
The word "energy" incidentally equates with the Greek word for "challenge."
Thomas Carr
Testimony before the U.S. Senate Commerce Committee
September 1974

INNOVATIVE TECHNOLOGIES

New Cell Growth

Nearly 90% of electricity-generating solar panels sold today are based on the original practical solar cell technology of the 1970s, which employs crystalline silicon. But these cells are expensive to fashion. Other, newer technologies may prove to be cheaper to make and more efficient at converting sunlight to electricity, with the added bonus of being less environmentally damaging to produce and use. Newest among these technologies is the dye-sensitized "titania" solar cell.

Just over a decade ago, Swiss scientist Michael Grätzel discovered a way to construct an efficient solar cell that relies on the interaction between a molecule-thick layer of an organometallic dye and titanium dioxide, or titania. Now, in an important step for what some call a promising technology, a small company called Sustainable Technologies International, with the aid of an Australian government grant of A$1 million (about US$526,000), has just opened the world's first manufacturing facility for a product that uses titania cells.



Midsummer day's dream? New solar panels coated with organometallic dye and titania promise to be more efficient and sustainable.

The company's first product is an electricity-generating, translucent, reddish-brown exterior wall panel. Its efficiency at converting sunlight to electricity is about 5%, well under the 10–16% efficiency of crystalline silicon technologies, and thus would need to be improved to really compete with those cells.

Titania cells work through an elegant "artificial photosynthesis" process. Sunlight hits the dye that coats the inner surface of a porous matrix of titania, which excites electrons. These electrons pass rapidly through the titania matrix, the spaces of which are filled by an electrolyte that supplies electrons to replace the ones lost by the dye. In turn, the electrons lost by the electrolyte are supplied by a second electrode. An electrical load connected between the two electrodes completes the circuit.

The primary advantage of titania cells, says Sylvia Tulloch, a materials scientist and executive director of Sustainable Technologies International, is that they are easier to make and thus cheaper to produce than other types of cells. Rather than using various types of semiconductors that require energy-guzzling machinery and clean room conditions, their artificial photosynthesis generating structures can be built with simple screen-printing equipment. As a result, she says, devices that incorporate these cells will cost less in the long run to make than those that use established technologies.

Titania cells may also prove to be safer for the environment than other technologies. Some of the materials used in silicon cell manufacture, such as carbon tetrachloride, are toxic. "They also use high temperatures and high vacuum, and so use a considerably amount of energy to manufacture," Tulloch says. However, titania cell manufacturing processes and the cells themselves are relatively benign, she says. Titania is nontoxic; in fact, it is used in many brands of toothpaste. The ruthenium dye that Sustainable Technologies International's first solar panels use, as well as the other materials, also present a negligible risk, says Tulloch. According to the draft National Renewable Energy Laboratory report *Assessment of the Dye-Sensitized Solar Cell*, the amount of toxic materials in a titania cell is just 25% of that in a crystalline silicon cell.

These differences, however, may not be particularly meaningful, according to Vasilis Fthenakis, a senior chemical engineer at Brookhaven National Laboratory who specializes in the potential environmental impacts of solar cells. "There are no significant environmental and safety hazards with any of [the types of solar cells] to the scale that they are manufactured today," he explains. And although there are some hazardous materials used, such as silane gas, cadmium, carbon tetrafluoride, and lead, he says, "if you look at the quantities in relation to their use in other industries, they are very, very small." But these risks will become more significant as the industry grows, he adds. And, according to Steve Hester, technical director of the utility–industry Solar Electric Power Association, current demand for solar cells is outstripping production, and the industry is expected to expand by as much as 40% per year into the foreseeable future.

By no means are titania cells the only potential alternative to crystallin silicon solar cells, however. Other developing technologies include amorphous silicon, cadmium telluride, and copper indium selenide. These others have a head start in both development and the market, says Robert McConnell, who manages research programs in nonconventional solar electric technologies for the National Renewable Energy Laboratory and wrote the lab's *Assessment*. "[Titania cells are]one of many promising solar electric technologies, and we don't have enough money to develop them all. And frankly they all have a fighting chance—this is a real horse race."
–Scott Fields

Sustainable Technologies International

ENERGY

A Disservice to the Environment?

Internet server "farms" fuel the high-tech industry by housing computer servers and networking equipment for businesses, both on- and offline, that require massive data processing. Server farms are measured in square feet; the total square footage of server farms increased ninefold in 2000. Today, in energy-starved California, 100 server farms in the Silicon Valley area consume more electricity than do a million families.

Proponents say server farms promote efficiency and cost savings for businesses by allowing them to outsource some of their data centers. Clinton Fein, president of the San Francisco–based ApolloMedia Corporation, which helps businesses develop Web sites, says server farms fulfill an existing need for the companies using them. If these locations did not exist, he says, the companies using them would be forced to provide these services for themselves. Fein believes the environmental impact of trucks driving to each of these individual locations to install computer lines and deliver equipment and generators, as well as the ongoing energy costs, should be weighed against the benefits of a centralized location where energy is more efficiently distributed on an as-needed basis.

But activist and community organizations such as the Silicon Valley Toxics Coalition (SVTC) of San Jose, California, would like to see a moratorium on the construction of server farms. They charge that the farms devour energy and that the diesel-fueled generators powering them threaten air quality.

The SVTC currently opposes the construction of a server farm in Alviso, California, that would sit close to a river and a wildlife refuge. According to the SVTC, unspecified studies show that air pollution created by the Alviso plant would be 2–4 times over the air quality thresholds that the Bay Area Air Quality Management District has established. If constructed, the one Internet farm in Alviso would use as much energy annually as 180,000 local households.

Jay Mendoza, director of the SVTC's Health and Environmental Justice Project, explains that the diesel pollution and particulate matter generated by the generators powering the plant would add to the physical burden that children and adults endure daily. "Children's asthma rates are rising, and this is placing an additional health threat on the working people of Alviso, who are on the poor side of the 'digital divide,'" he says.

Community leaders and activists in San Francisco's Mission District also have no doubt about the environmental health impact of server farms. They oppose the construction of a proposed 340,000-square-foot server farm, one of 16 in San Francisco operating or coming online soon. One of their biggest concerns is that residents will breathe in diesel fuel generator–produced pollutants such as dioxins, carbon monoxide by-products, sulfur oxide, and nitrous oxide, which mixes with oxygen in the atmosphere to produce ozone.

Server farms account for about 1.4 million square feet of San Francisco's commercial and industrial property. Their growth is unregulated, and that concerns city officials. "Technology is usually ahead of city planning codes, but we're moving to tighten the review process under which server farms are approved and constructed," says Greg Asay, a San Francisco city government official. The regulations, which the city government is expected to approve in January 2002, would tie the future operation of server farms to certain requirements, including the use of environmentally friendly back-up power systems and the creation of special buffer zones that separate residential areas from business zones.

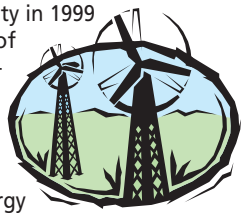
At this point, however, there are no data on how server farms actually affect the environment; they are such a new phenomenon that no studies have yet begun. "We would be willing to act on the health issues [critics] talk about if the science was there," Fein says.

Meanwhile, in the high-tech boom area of Seattle, some two dozen server farms are in the works. That concerns the Portland, Oregon–based Northwest Power Planning Council, an interstate compact involved in the long-range planning for power needs of the Pacific Northwest. The council completed a study last year that predicted a 24% chance of winter power outages in the Washington, Oregon, Idaho, and Montana region by 2003.

"In our planning, we've taken into account that server farms are going to be built in the region," says John Harrison, the council's information officer. One Internet server farm can consume a large portion of an area's power, he says—a serious problem in a region where power is scarce and expected to get scarcer in the future. **–Ron Chepesiuk**

Top to bottom: EyeWire; WWF; James Catallo

A Change in the Air



The American Wind Energy Association and the European Wind Energy Association announced in May 2001 that the addition of new wind energy capacity in 1999 and 2000 outpaced that of added nuclear energy capacity. During those two years, 7,400 megawatts of wind energy capacity was added, compared to 5,756 megawatts of nuclear energy capacity. Wind energy is clean to produce and doesn't pose the same siting and waste storage problems as nuclear energy, making it an attractive alternative for policy makers looking to reduce pollution and energy costs.

A Swish for the Swoosh

Nike has signed a Climate Savers memorandum of understanding with the World Wildlife Fund and the Center for Energy & Climate Solutions to reduce greenhouse gas emissions from its company-owned operations and subcontracted manufacturing and shipping operations worldwide. Under the agreement, the organizations will work with Nike to help it reach three goals: reduce CO_2 emissions to 13% below 1998 levels by 2005, create "best practices" standards for its major subcontracted manufacturing facilities by the end of 2003, and examine its supply network to determine a greenhouse gas reduction strategy focused on improving efficiency. Corporations already participating in the Climate Savers program include IBM, Johnson & Johnson, and Polaroid.

Scrap Exchange

A new process that makes a petroleum-like product from biological materials such as fishery wastes, yard clippings, fryer fat, and animal wastes could eliminate the environmental impact of petroleum exploration and production. The patented process, developed by Louisiana State University environmental chemist James Catallo, converts biomass to a hydrocarbon mixture similar to low-sulfur petroleum through a reaction with water occurring under supercritical or near-critical conditions.

In light of predictions that the world's petroleum deposits will be exhausted within this century, Catallo says the process could help meet the high demand for fuel and hydrocarbon-based product such as plastics, coatings, and solvents.

ALTERNATIVE FUELS

The Economics of Ethanol

The conversion of corn into ethanol to produce gasohol (a gasoline–ethanol mixture) is touted by some scientists as an economical and environmentally cleaner alternative to fossil fuels. However, ethanol production is neither economical nor environmentally sound, concludes David Pimentel, a professor of insect ecology and agricultural science at Cornell University in Ithaca, New York. According to a study by Pimentel that appears in the third edition of the *Encyclopedia of Physical Science and Technology*, published in October 2001, 1.7 times more energy is required to grow and process corn and then distill the ethanol than is obtained from burning it. "The myth is that ethanol frees us from dependence on oil, yet we actually import oil to run ethanol plants and grow corn," Pimentel says.

In addition, most other economic calculations of ethanol production have ignored the costs of environmental damage associated with corn production. "Corn uses more herbicides and pesticides than any other U.S. crop," says Pimentel. In addition, he says, corn production erodes soil about 12 times faster than the soil can be naturally reformed, and irrigating corn depletes groundwater 25% faster than the natural recharge rate. Pimentel calculates that if the average automobile in the United States, traveling 10,000 miles a year, were to be fueled by ethanol, seven times more cropland would be required for fuel than is currently devoted to feeding one American citizen. He further contends that if the current $1 billion in federal and state subsidies were dropped, ethanol production "could not float on its own."

In contrast, *Estimating the Net Energy Balance of Corn Ethanol: An Economic Research Service Report*, a 1995 report by Hosein Shapouri, James A. Duffield, and Michael S. Graboski of the U.S. Department of Agriculture, claims that the net energy content of ethanol runs 1.2 times more than the fossil energy needed to produce it. Experts agree that differences in corn yields, credit for the energy content of nonethanol by-products such as distillers and grains, varied technologies used at different processing plants, and the regional costs of machinery, fertilizer, irrigation, and transportation contribute to the discrepancy between the two studies' findings. "The analysis is difficult because there's a wide range of processing plants operating at different efficiencies using different equipment and technology," says chemical engineer George Robertson of the Agricultural Research Service Western Regional Research Center in Albany, California.

Robertson sees changes pointing toward economic feasibility. For instance, his laboratory has developed enzyme variants that convert cornstarch into sugars (for fermentation into ethanol) over 50 times faster and at lower temperatures than the original enzymes, making production more energy-efficient. At the biotechnology company Genencor International in Palo Alto, California, researchers are designing enzymes to make ethanol from the cellulose in cornstalks. (Cornstalks are a cheaper raw material than kernels, and using cellulose avoids competion with food markets for kernels.) In addition, new ethanol plants are built near feedlots, and corn by-products are sold as cattle feed to offset processing costs.

As for subsidies, "they got the ethanol industry on its feet," Robertson says. As ethanol processing evolves and the world's finite oil supply dwindles, he predicts that subsidies for ethanol will disappear and the ethanol industry will be able to support itself. Moreover, he says, the oil industry is subsidized indirectly by military and diplomatic activities abroad to ensure a continuous oil supply. Yet, Robertson points out, "There's no need for a military force in our Midwest to ensure a continuous supply of corn to produce ethanol." **–Carol Potera**

RECYCLING

Switching to Switchgrass

Biomass fuels offer a tantalizing sidestep around global warming. When burned, they produce the greenhouse gas carbon dioxide, but their growth takes up a similar amount of the gas, thus producing essentially no net increase in atmospheric carbon. Almost all biomass fuel is waste residue from forestry, agriculture, or industry, and biomass fuels can also be grown as crops. Several recent demonstration projects have tested the use of switchgrass, a perennial prairie grass native to North America, in electric generating stations.

Biomass fuels are second only to hydropower as a fuel for mass utility-administered consumer use. In May 2001, for example, biomass generated about 1.8% of the total 307 trillion kilowatt-hours produced that month, according to U.S. electric power industry summary statistics published by the federal Department of Energy (DOE).

In a test cosponsored in December 2000 by the DOE, the Centerville, Iowa–based nonprofit Chariton Valley Resource Conservation and Development, and the utility holding company Alliant Energy, switchgrass was burned at a generator in Iowa. Thirteen hundred tons of switchgrass was harvested with a hay baler, chopped into short pieces, and burned with coal in a 725-megawatt boiler. The generator ran normally, with switchgrass supplying up to 13 megawatts of electricity. "You could not tell you were running switchgrass," says Richard Bain, the biopower group manager in the National Bioenergy Center at the National Renewable Energy Laboratory in Golden, Colorado. Recently Southern Company, a large electric utility in the southeastern United States, successfully completed a similar test in Gadsden, Alabama, with switchgrass contributing 7–10% of the energy produced during the test period.

Douglas Boylan, a research engineer with Southern, says switchgrass and similar

Budding biomass. A one-acre plot of switchgrass can grow the energy equivalent of about 2–6 tons of coal per year.

Warren Gretz, DOE/NREL

Institute for Energy and Environmental Research

For many people around the world, 2001 was unusually fraught with anxieties over energy. The year began with rolling electric power blackouts in California that affected more than 1 million people. Debates raged over controversial hydroelectric dam projects—such as a $2.4 billion project in Borneo and the $24.65 billion Three Gorges Dam in China—and the possibility of opening 2,000 acres of coastal plain in Alaska's largely untouched Arctic National Wildlife Refuge for oil exploration. Germany and France saw huge antinuclear riots. Anxieties were further intensified as the conflict in Afghanistan again focused the world's attention on the security and availability of petroleum flowing from that region.

To alleviate these energy anxieties as well as those related to reducing the effects of pollution and global warming, many countries are working to develop energy self-sufficiency and sources of renewable energy. A side effect of these efforts is that worldwide interest in nuclear energy is growing.

Established in 1987, the Takoma Park, Maryland–based Institute for Energy and Environmental Research (IEER) focuses on the environmental safety of nuclear weapons production as well as on ozone layer depletion and other energy-related health and climate issues. The IEER collects and publishes a variety of materials on energy-related issues, which are available on the institute's home page, located at **http://www.ieer.org/**. The institute also conducts workshops for activists on nuclear issues, worked successfully to add carbon tetrachloride to the list of banned ozone-depleting chemicals, and sponsors international symposia and educational outreach projects, all of which are discussed on the IEER Web site.

On the site's About IEER page, the organization discusses another of its aims, which is to make technical information in nuclear and energy technology and related fields more accessible to nonscientists. To that end, the institute's English-language quarterly newsletter *Science for Democratic Action*, accessible from the home page, provides accessible yet technical information on topics such as plutonium cleanup and disposal. As part of its global outreach work, the IEER's newsletter *Energy & Security*, also available from the home page, is provided in Chinese, Russian, Japanese, and French. Each edition of this newsletter is themed, with past issues spotlighting nuclear plant risks, cleaning up after the Cold War, and nuclear power as a faulty solution to global climate change. Selected books, press releases, and articles are also provided in multiple languages.

The Subject Index link on the home page leads to a directory of links for 15 main subjects, including Health and Safety, Nuclear Power, and Energy Issues. Links are provided for hundreds of newspaper and magazine articles, conference briefings, fact sheets, and IEER commentary, with the most recently added items highlighted for easy identification. **–Erin E. Dooley**

biomass crops have several environmental advantages over coal, which, according to the DOE, fuels about 40% of U.S. utility electric generation. The emissions, he says, are very low in sulfur dioxide and mercury, two major pollutants associated with coal.

One acre of a switchgrass plot can grow the energy equivalent of about 2–6 tons of coal per year, says Bain, depending on fertilization and other variables. Boylan says one large bale of switchgrass produces enough power to serve a typical house's electricity needs for a month.

Growing switchgrass is also a sustainable practice in itself. Biomass crops typically produce 15–25 times as much electric energy as the heat energy in the fossil fuels needed to grow, process, and transport them, Bain says. Research by Resource Efficient Agricultural Production (REAP), a Canadian nonprofit group that studies sustainable fuels and agricultural practices, indicates that switchgrass requires only modest amounts of fertilizer for optimal growth. Switchgrass grows year after year in one location without recurrent soil preparation, greatly reducing soil erosion and runoff associated with annual tillage that might be needed for other biomass crops. And as a wildlife habitat, switchgrass is better than row crops, says Roger Samson, director of international projects for REAP.

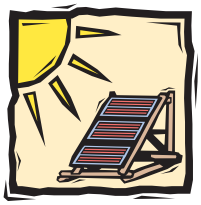
Some say switchgrass's true strength lies in being used directly to warm buildings or to replace wood as a cooking fuel. Samson says burning switchgrass in coal-fired generators produces about 32% efficiency, but when switchgrass is pressed into pellets and burned in specially designed space-heating stoves, the efficiency reaches 85%.

About the only bad mark on the switchgrass scorecard is economics. Although the exact price is not yet clear, in tests to date switchgrass appears to cost more than coal to produce electricity. "I think using dedicated crops like switchgrass is going to be more expensive than coal," Bain says, "but it will depend on the specific system." Samson agrees that switchgrass costs more than coal to produce electricity, but adds, "Switchgrass pellets provide heat for about thirty percent less than heating oil."**–David J. Tenenbaum**

EyeWire

Mass-Producing Solar Cells

Under an agreement announced in October 2001, Shell Renewables and Akzo Nobel will develop a low-cost process for mass-producing solar cell panels. In the process, a special solar cell coating just a few microns thick is applied to rolls of a flexible foil substrate. Until now, solar panels have been costly due to the expense of materials such as pure silicon, glass, and metals, coupled with labor-intensive manufacturing processes. The technology for faster and cheaper cells could stimulate a broader market for solar power by allowing cost-effective integration into existing solar products, roofing, and wall materials, as well as encouraging new applications for solar panels.



Developing Energy Alternatives

The UN Foundation has approved two grants to assist poverty-stricken rural areas in Africa and Brazil in obtaining clean and affordable energy. An additional $2.3 million dollars will go to the African Rural Energy Enterprise Development (AREED) program, begun in 2000 by the UN Foundation and the UN Environment Programme. AREED's goal is to support entrepreneurs who can establish climate-friendly technology businesses with modest initial financing. So far, 30 businesses have been launched, providing energy services from sources including solar, wind, and biomass.

The second grant of $2.1 million will help extend the AREED approach to Brazil, where 20–40 million people in the north and northeast regions lack access to electricity.

New EU Stamp of Approval

The European Union has revised its eco-labeling programs for personal and portable computers and dishwashers. Changes for dishwashers include a major overhaul of product requirements, including lower water consumption and noise limits, in addition to requirements for free end-of-life recycling. New requirements for computers include increased energy efficiency and durability, exposure limits for electromagnetic emissions, a more specific recycling policy, crystal displays.

The program, started in 1993, allows products meeting the labeling standards to display a special flower logo and requires reviews of standards every three years. Criteria are being developed for other product groups including televisions, tires, and vacuum cleaners.