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6 Get Grants From U.S. To Support Bio-Refineries

By ALEXEI BARRIONUEVO; MATTHEW L. WALD CONTRIBUTED REPORTING.

Seeking to encourage motor fuel production from materials that are cheaper and more abundant than corn, the Energy Department said yesterday that it would provide up to $385 million in six bio-refinery projects that would produce cellulosic ethanol, a type of ethanol that can be made from nonfood crops and agricultural waste.

The awards, to be made over four years, are called for under the 2005 Energy Policy Act. They will advance President Bush's goals of making the cost of cellulosic ethanol competitive with gasoline by 2012 and of reducing America's gasoline consumption by 20 percent in 10 years, Energy Secretary Samuel W. Bodman said at a news conference in Washington.

Dozens of ethanol refineries that use corn are planned for construction over the next two years. But Mr. Bodman acknowledged yesterday that corn alone would not be enough to achieve the ambitious goal of taming what Mr. Bush has called America's "oil addiction."

Because of constraints on farmland and the need for corn in the food supply, corn-based ethanol can produce only up to 15 billion gallons of ethanol, less than half of the 35 billion gallons of renewable and alternative fuels the president set as a goal by 2017 in his State of the Union speech in January.

"Corn-based ethanol is already playing a key part in reducing our dependence on fossil fuels and mitigating the growth of greenhouse gases, but we cannot increase our use of corn grain indefinitely," Mr. Bodman said.

Ethanol made from corn has a small effect on greenhouse gases, but ethanol from cellulose cuts those gases sharply.

But cellulosic ethanol is still twice as expensive as corn-based ethanol, which has relied for many years on a 51-cent-a-gallon subsidy to be competitive with gasoline. For that reason, no company has yet to construct a commercial-scale cellulosic plant.

Mike Muston, executive vice president of Broin Companies, which won one of the awards, said Broin could produce cellulosic ethanol for $2.25 to $2.50 a gallon and expected to cut those costs to under $2 a gallon when it started its plant around 2010. Mr. Bodman said the long-range goal was to get costs down to $1 a gallon, which he said would put cellulosic ethanol in position to compete with "any technology in the world."

Yesterday's grants will help accelerate the nascent cellulosic industry, Mr. Muston said, allowing Broin, which is based in Sioux Falls, S.D., and its partner, DuPont, to push up construction on an expansion to its Emmetsburg, Iowa, plant by two to three years.

Lawrence J. Goldstein, an energy consultant and critic of corn-based ethanol, said the administration had no choice but to push hard to commercialize cellulosic ethanol. "They are throwing money where they ought to be throwing it because they know they can't get within shouting distance of their goal without a major, quick breakthrough in cellulosic," said Mr. Goldstein, a board member at the Energy Policy Research Foundation.

The awards will finance up to 40 percent of the projects, which are expected to total more than $1.2 billion. The projects, which are scattered from Florida to Kansas to California, aim to produce more than 120 million gallons of cellulosic ethanol a year.

The winning companies, in addition to Broin, are a Spanish company, Abengoa Bioenergy; Alico Inc., of LaBelle, Fla.; BlueFire Ethanol, based in Irvine, Calif.; the Iogen Corporation, of Canada; and Range Fuels, of Broomfield, Colo. Range Fuels is partly financed by Khosla Ventures, the Silicon Valley venture capital firm run by Vinod Khosla, an influential voice on ethanol in Washington.

The plants would use low-value materials like switch grass, wheat straw and wood chips.

Even with the new push by the Energy Department, Mr. Bodman said ethanol's future was not assured.

"We are unclear whether ethanol will be the winner," he said yesterday, referring to the search for a renewable energy source to replace petroleum. Bio-butanol, a crop-based fuel that is to be commercialized later this year by DuPont and the oil giant BP, "is an inherently better fuel," he said, because, unlike ethanol, it has as much energy for each gallon as gasoline does.

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THE ENERGY CHALLENGE

A Renewed Push for Ethanol, Without the Corn

By MATTHEW L. WALD and ALEXEI BARRIONUEVO

JENNINGS, La. — The sun shone brightly on the crowd gathered at the rusting old oil refinery here, as company officials showed off diagrams explaining how they planned to turn weeds and agricultural wastes into car fuel.

Government officials gave optimistic speeches. In the background, workers prepared a new network of pipes, tanks and conveyor belts.

That was in October 1998, when ethanol from crop wastes seemed to be just around the corner.

It still is. Last February, company officials gathered here once again, to break ground on a plant designed to make ethanol by yet another method.

At the time of the first ceremony, the Energy Department was predicting that ethanol produced from cellulosic waste would be in the market by about 2009 in the same volume as ethanol from the conventional source, corn.

But no company has yet been able to produce ethanol from cellulose in mass quantities that are priced competitively with corn-based ethanol. And without the cellulosic ethanol, the national goal for ethanol production will be impossible to reach.

"Producing cellulosic ethanol is clearly more difficult than we thought in the 1990s," said Dan W. Reicher, who was assistant secretary of energy efficiency and renewable energy at the time of the first ceremony and who spoke here then.

To be sure, swarms of innovators, venture capitalists and government officials are optimistic. Over the last year, money has begun to pour in from all corners — government, private foundations, venture capitalists and Wall Street — to sort out the myriad production problems preventing cellulosic ethanol from becoming a reality. And recent advances in gene sequencing have raised hopes for a breakthrough in mass producing the enzymes needed to do the work.

If making the technology work to produce ethanol from cellulose was important in the 1990s, it is even more critical now. Because of growing concerns about oil imports and climate change, Mr. Reicher said, "it is essential that we figure this out, and fast."

Mounting concerns over excessive demands for corn as both food and fuel only add to the urgency. In January, President Bush set a goal of producing 35 billion gallons of alternative fuels, probably mostly ethanol, by 2017.

But the more than six billion gallons of ethanol that will be produced this year have already helped push corn to its highest price in years, raising the cost of everything from tortillas to chicken feed. Poor people in Mexico have protested against the higher prices, and now China and India are starting to suffer from food inflation.

So why has no one figured out a way to make ethanol from materials like the sugar cane wastes engineers are working with here?

In fact, engineers at several companies have done that — but only at the lab level. One company, Iogen, has a pilot plant running in Ottawa and hopes to build a larger operation soon.

Abengoa, a Spanish company, says it plans to open a plant in northern Spain late this year, and wants to build a factory in Kansas. Broin Companies, of Sioux Falls, S.D., is planning to expand a corn ethanol plant in Emmetsburg, Iowa, to use cellulose as well.

But everyone is still struggling to develop a method that is cost competitive with corn ethanol — not to mention competing with gasoline and other fuels from oil without subsidies.

The pilot plant that opened here in 1998, after the first ceremony, "worked like a charm," said Russell Heissner, a biofuels expert at Celunol, the company building the Jennings plant. But Celunol, then called BC International, shut it after a few months because of a lack of money and because it could not figure out how to turn the process into a commercial-scale project.

Now the company is building a much larger plant to tackle another part of the cellulosic puzzle.

The broad concept is the same everywhere. Yeast is used to turn sugar into alcohol, a process learned thousands of years ago. The easiest way to get sugar is from sugar cane. Corn provides carbohydrates, long chains of starch that are easily broken into sugars.

Mr. Heissner is hopeful that stems, stalks, wood chips and other materials will replace the corn. The founding brew master at Harpoon, a Boston beer brand, Mr. Heissner later designed and built microbreweries and pubs.

That experience is relevant. Beer is made from barley, a seed, or cereal grain, like corn. It is exposed to warmth and moisture that resemble the conditions for germination, and the barley begins to produce an enzyme that converts its starch into sugar. The brew master roasts the barley to kill the plant, but the enzyme continues to convert the starch to sugar. Hops are added for flavor, and then yeast is added to convert the sugar to alcohol.

Cellulose is also made up partly of sugars, but they are linked tightly in a more complicated chain. Breaking them up requires several enzymes. Most processes start with using steam and sulfuric acid on the feedstock, which can be corn stems and leaves, switch grass, wood chips — or bagasse, the material left when sugar cane is processed and which is being used here in Jennings.

Manufacturers rely on a variety of organisms to make the necessary enzymes. They are the product of gene splicing, turning out enzymes in quantities far greater than any natural organism would.

Unlocking the sugar represents a gold mine. Mark Emalfarb, the president and chief executive of another competitor, Dyadic, said corn now makes up about half the price of corn ethanol, while some cellulosic materials are free, beyond the cost to haul them to a factory.

But the enzymes needed to break corn starch into sugar are cheap, costing 3 to 5 cents a gallon of ethanol. His goal for the enzymes that work on cellulose is 10 cents a gallon, but it does not appear that anyone has gotten the cost anywhere near that low yet.

"Some people are still underestimating how difficult it is going to be," Mr. Emalfarb said.

The Energy Department has set a goal of bringing down the overall cost to produce cellulosic ethanol to $1.07 a gallon by 2012. That is less than half the cost of producing it now and lower than the current cost of about $1.50 a gallon for corn-based ethanol.

"Anybody's number is just basically a guess," said Brent Erickson, executive vice president at the Biotechnology Industry Organization in Washington. "Until we get these plants built, we aren't going to know what the cost is."

The race to commercialize cellulosic ethanol has been helped by the recent flood of investment from public and private sources.

The Energy Department has devoted $726 million for renewable energy projects this year, including wind and solar energy. It recently awarded grants totaling $385 million over four years to six companies working on cellulosic ethanol plants. The Agriculture Department is seeking to increase its bio-energy financing to $161 million from $122 million, which would include $21 million in loan guarantees for cellulosic plants.

Venture capital firms, Wall Street banks and even oil companies have invested about $200 million in the last six months alone."There is nothing in the last several decades that has generated such private sector enthusiasm and investment," said Keith Collins, the Agriculture Department's chief economist.

The investment is risky but the potential benefits are enormous. A cellulosic ethanol process would raise the ethanol yields from sugar cane by about one-third an acre by using parts of the sugar plant that are now thrown away as waste. For corn wastes, the number is similar.

The cellulosic process also promises to use less energy than corn-based ethanol. And it can work on material that is not currently considered a crop, like switch grass or wood chips left over from paper making.

In Louisiana, Celunol is experimenting with an aboriginal sugar cane that grew 200 years ago, before farmers started selectively breeding for the varieties with more sugar. Native to the local environment, "it doesn't need fertilizer and it grows everywhere, like weeds," said Matthew Gray, a research engineer with the company.

Mr. Heissner, who studied viniculture and enology at the University of California, Davis, said he was happy to move from microbreweries to vehicle fuel, which would be a much bigger business, he predicted.

Andrew Karsner, the current assistant secretary for energy efficiency and renewable fuels, said that he agreed. The original Jennings project, despite its earlier failures, was simply "well ahead of the killer wave that is here with us now."

Matthew L. Wald reported from Jennings, La., and Alexei Barrionuevo from Chicago.

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March 28, 2007

A Rush for Uranium; Mines in the West Reopen as Ore Prices Reach Highs of the 1970s

By SUSAN MORAN AND ANNE RAUP

Given its connotations, Pandora is an oddly inappropriate name for an uranium mine.

But that does not seem to bother Denison Mines, the company from Vancouver, British Columbia, that owns it. Denison recently reopened this mine about 30 miles southeast of Moab, along with several others in nearby western Colorado, after it lay dormant during the years when the nation shunned nuclear power.

The revival of uranium mining in the West, though, has less to do with the renewed interest in nuclear power as an alternative to greenhouse-gas-belching coal plants than to the convoluted economics and intense speculation surrounding the metal that has pushed up the price of uranium to levels not seen since the heyday of the industry in the mid-1970s.

"There's a lot of staking going on," said Mike Shumway, a 53-year-old Vietnam veteran who owns the contracting business that is working the Pandora mine. "It's like the gold rush."

Mr. Shumway has personally amassed some 100 uranium claims, including four dormant but potentially rich mines. Some of the claims he bought quietly after less tenacious prospectors could not afford to hold theirs during the long drought while uranium was out of favor. Mr. Shumway's eyes light up and he cracks a grin as he ponders the fortune he now hopes to gain.

"There's big money in it," he said as he probed piles of waste ore at Pandora with a Geiger counter. "What other work do you know of where you can make millions in 30 days?"

Not many. Prices for processed uranium ore, also called U308, or yellowcake, are rising rapidly. Yellowcake is trading at $90 a pound, nearing the record high, adjusted for inflation, of about $120 in the mid-1970s. The price has more than doubled in the last six months alone. As recently as late 2002, it was below $10.

A string of natural disasters, notably flooding of large mines in Canada and Australia, has set off the most recent spike. Hedge funds and other institutional investors, who began buying up uranium in late 2004 to exploit the volatility in this relatively small market, have accelerated the price rally.

But the more fundamental causes of the uninterrupted ascendance of prices since 2003 can be traced to inventory constraints among power companies and a drying up of the excess supply of uranium from old Soviet-era nuclear weapons that was converted to use in power plants. Add in to those factors the expected surge in demand from China, India, Russia and a few other countries for new nuclear power plants to fuel their growing economies.

"I'd call it lucky timing," said David Miller, a Wyoming legislator and president of the Strathmore Mineral Corporation, a uranium development firm. "Three relatively independent factors -- dwindling supplies of inventory, low overall production from the handful of uranium miners that survived the 25-year drought and rising concerns about global warming -- all have coincided to drive the current uranium price higher by more than 1,000 percent since 2001."

Strathmore controls more than three million acres of exploration projects in Canada and previously discovered sources in the United States, primarily around Grants, N.M. In its heyday, the Grants "uranium belt" provided 340 million pounds of uranium, making New Mexico an even larger producer than Utah or Wyoming. Some politicians in the area hope there will be a new wave of mines, mills and jobs.

Strathmore, with a market capitalization of $300 million, is one of about 400 publicly traded uranium stock companies (most of them, like Strathmore, trade on the Toronto Stock Exchange). Many of the companies are much smaller. Some are essentially shells.

"There's so much money pouring into this sector," said Julie Ickes, editor and publisher of StockInterview.com, which tracks uranium prices and companies. "If you put 'uranium' in your company name, you can look like you're looking for property," he said. "It's a lot of talk."

The feverish trading in speculative uranium company shares harks back to the early 1950s, when some 500 stocks traded on the Salt Lake City Penny Stock Exchange. Moab called itself "the uranium capital of the world."

"You could say there were more millionaires than people here in Moab," said Sam Taylor, 73, who has been publisher of the local weekly, The Times-Independent, since he took it over from his father in 1956.

Sitting stooped over his wooden desk at the newspaper's office downtown, Mr. Taylor recalls how he got "the scoop of the century" when a young, cocky geologist named Charlie Steen pulled up in his battered jeep asking if The Times-Independent would publish his six-page paper on his recent discovery of pitchblende, or high-grade uranium.

Not long after, Moab lost its quietude and anonymity to the ore trucks roaring through town almost around the clock to deliver uranium to a mill on the north edge of town.

Globally, 180 million pounds of processed uranium are consumed each year by nuclear power plants. Production worldwide from mines amounts to only 100 million pounds. Roughly 75 million pounds come out of utility company stockpiles. What is actually traded in the spot market is only about 35 million pounds.

Some industry watchers fear the uranium market is entering the bust phase of another boom-bust cycle.

"It's like the tech bubble," said James Finch, senior editor of StockInterview.com. "We're waiting for the crash."

But others see plenty of room for prices to climb. One is Bob Mitchell, founder of Adit Capital, a small hedge fund in Portland, Ore. In December of 2004, he became one of the first hedge fund managers to start buying uranium.

Since then other hedge funds and institutional investors have jumped into the market, some of them hoarding uranium while the price keeps rising. Even some established mining production companies are spinning off or becoming partners with hedge funds.

Uranium executives, investors and analysts alike agree that a major underlying cause of the current bull market is that mines are not generating enough uranium to meet growing demand. The supply constraints can be traced back to the end of the cold war when the United States and the former Soviet Union started converting enriched uranium from dismantled atomic weapons into nuclear fuel for peaceful purposes.

That program, and huge incentives offered to uranium companies by the Nuclear Regulatory Commission, flooded the market with excess supply. At the same time, demand shrank. The price of uranium fell sharply.

As a result, most uranium producers scaled back or closed their mines. Some companies sold themselves to French, Canadian and British corporations, which now dominate the industry. Some companies with nuclear power operations sold some of their inventories when the price was low to avoid storage costs.

But by 2003 uranium inventories held by utilities in the United States were coming back into balance. Then a series of natural disasters -- flooding of the world's largest uranium mine, McArthur River in Canada, and more recently at other mines in Canada and Australia -- further pinched supply. Power companies now find themselves competing with aggressive institutional investors for high-price uranium.

"For so long they'd been the buyer in a buyer's market," said Gene Clark, chief executive of TradeTech.com, a publisher of reports and data on the nuclear fuel market. "Now they're like a wallflower. It's hard on their egos."

James Malone, vice president of nuclear fuels at the Exelon Corporation, the Chicago-based utility that owns 17 reactors at 10 sites, making it the largest nuclear operator in the country, said in a telephone interview that current market conditions were having a "small impact" on some of the company's contracts that were pegged to the market price. He declined to elaborate.

The people staking claims and drilling underground are, in the meantime, happy to see the frothy market become frothier. So far this year, 2,700 new uranium claims have been filed with the Bureau of Land Management in Colorado alone. That is nearly half the claims filed in all of last year, and a big jump from the 104 claims for 2004.

"It's pretty spectacular," said Jesse Broskey, a land law adjudicator with the bureau. "It's tripled our workload."

But many people in the region, including leaders of the Navajo Nation, are not particularly excited to invite Pandora and other participants in the nuclear industry back into their communities. They say the mining and power companies poisoned workers and residents, in some cases fatally, with radon, silica and tainted groundwater.

More stringent federal oversight means that mines built or refurbished today provide much better ventilation, which minimizes the underground risks. Mine operators are required to take readings of radon levels and air flow in the mines, and to measure miners' exposure doses.

Another red flag, for environmentalists and utilities alike, is the lack of a national storage site for radioactive waste. The proposed home, Yucca Mountain in Nevada, has cost taxpayers billions over many years as it sits idly, waiting for a final decision.

That is one of several factors holding back the revival of nuclear power in the United States. "We won't build a new plant knowing there's nowhere to put the used fuel," Mr. Malone of Exelon said. "We won't build one without community support, and we won't build until market conditions are in place where it makes sense."

But that is not holding back Kyle Kimmerle, owner of the Kimmerle Funeral Home in Moab. Mr. Kimmerle, 30, spent summers during his childhood camping and working at several of his father's mines in the area. In his spare time he has amassed more than 600 uranium claims throughout the once-productive Colorado Plateau.

"My guess is that next year my name won't be on the sign of this funeral home anymore and I'll be out at the mines," he said.

He recently struck a deal with a company to lease 111 of his claims for development. The company, new to uranium mining, has pledged $500,000 a year for five years to improve the properties. Mr. Kimmerle will receive annual payments plus royalties for any uranium mined from the area.

"Everybody's jumping in while the price is going up," he said. "Sure, it'll eventually go down. It's not going to be in three years. But after 10 years I'd say all bets are off."

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APS physics

New Series on Versatility in Physics debuts on page 5

APS Panel Report Assesses Nuclear Waste Storage Issues

Approximately 54,000 tons of spent nuclear fuel are stored at operating nuclear power plants and several decommissioned power plants throughout the country. The APS Panel on Public Affairs (POPA) has recently released a report assessing some of the issues involved in developing one or more consolidated interim storage sites where this nuclear waste could be stored until a permanent repository at Yucca Mountain is opened.

Current storage facilities at reactor sites were not meant to be permanent, but the schedule for opening Yucca Mountain continues to slip. The federal government is incurring increasing liability costs the longer spent fuel remains at reactor sites, and there is concern that continuing to store spent fuel at power plants will make it more difficult to find sites for new nuclear power plants and to build them.

Recently, appropriations committees in Congress have suggested building one or more consolidated interim storage sites for the spent fuel. The POPA Nuclear Energy Study Group examined issues associated with the centralized interim storage of spent nuclear fuel and has issued a technical and programmatic assessment.

"We found no major technical benefit to developing a consolidated interim storage site," said John Ahearne, one of the study group co-chairs. There may be some programmatic benefits to a consolidated storage site, he said.

One advantage of a consolidated storage site is that it could "relieve impediments to the growth of nuclear power," the report says. A consolidated site would decouple the private sector nuclear power plant operators from uncertainties inherent in the federal long-term spent fuel management program, the report notes. "The assurance that spent fuel can be removed from a reactor to a storage site may reduce the difficulty in siting new plants," the report says.

The study group determined that there are no technical barriers to long-term safe and secure interim storage either at nuclear reactor sites or at a consolidated site. "The safety and security risks associated with storage of spent fuel are not appreciably different whether the fuel is stored at plant sites or in one or more consolidated facilities," the report states.

Even if Yucca Mountain opens as scheduled in 2017, it will take several decades to move all the currently stored spent fuel to the site. Interim storage, either at reactors or at one or more consolidated sites, will still be necessary, the study group reports. The study group also found that there is sufficient storage capacity at current nuclear reactors to hold all spent fuel for the duration of the plant licenses.

If Congress decides to develop a consolidated interim storage facility, there will be challenges in selecting and approving a site. However, the study group suggests that these siting challenges can be overcome by finding ways to make the facility

POPA continued on page 4

…es New Math and Science Education Initiative

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more attractive environmentally and economically to the host community. It would be necessary to make sure a consolidated interim site and the Yucca Mountain repository proceed in a complementary way, in a manner consistent with current Federal strategies for long-term nuclear waste management, the study reports. The Yucca Mountain site must not be delayed by an interim site, and it would be necessary to assure the public that an interim site would not become permanent, the report says.

If the Yucca Mountain repository is not delayed significantly beyond its currently scheduled opening, there is no economic benefit to a consolidated interim storage site, the study finds. "There are no compelling cost savings to the Federal government associated with consolidated interim storage," the report states. If, however, Yucca Mountain is significantly delayed, Congress would need to request an independent review to determine whether a consolidated interim storage site would be economically attractive, the report says.

The full report is available online under "Reports and Studies" on the Policy and Advocacy page of the APS web site.

In addition to the nuclear waste storage report, the APS Panel on Public Affairs is conducting research on advancing electricity storage technologies. The POPA Committee on Energy and Environment has recently released a policy supplement on this issue.

The supplement describes promising energy storage technologies and R& D opportunities for developing these technologies. The six technologies are pumped hydropower, compressed air energy storage, batteries, flywheels, superconducting magnetic energy storage, and electrochemical capacitors.

Electricity storage technologies have the potential to reduce the need for reserve power plants, cut the cost of power failures, and enable renewable energy, the supplement says. The committee concludes that the Department of Energy should consider broadening its existing program for electricity storage technologies, while balancing basic research, demonstration projects, and regulatory incentives.

Photo Essay

Good Day Sunshine

One of the largest solar power plants in the world went on line this winter in the sunny pastures of Serpa, a town in southern Portugal. The plant is owned by General Electric and operated by PowerLight of Berkeley, CA. At its peak, around noon on a sunny day, the solar park can generate 11 megawatts of electricity—enough to power 8,000 homes.

By Katherine Bourzac Photographs by Antonio Luis Campos

The Serpa plant's 90 acres are covered by 52,000 panels that support nearly four million solar cells (black squares, opposite page). Howard Wenger, executive vice president of PowerLight, says that building a solar park this large offers economies of scale: it is less expensive than installing the same number of solar cells in smaller plants or on the roofs of individual businesses and homes. The park cost General Electric $75 million and is expected to turn a profit. Portuguese utilities are required to purchase electricity from the plant, with a federal subsidy of a few cents per kilowatt-hour. Customers whose utilities buy solar power will see less than a tenth of a percent increase in their electric bills. Wenger expects the plant to produce 21,340 megawatt-hours of electricity each year, reducing the region's carbon dioxide emissions by 13,000 tons over the same time period.

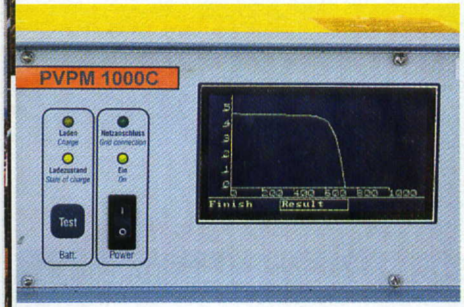
Serpa is about as sunny as central California. But even on a stormy day, the plant is productive. Sensor stations like the one above monitor the weather and the sun's location and control the angle of groups of solar panels. PowerLight's Wenger compares the rows of panels to slats on Venetian blinds: long, motor-powered metal beams attached to the panels adjust their angle throughout the day. In the morning, the panels angle to catch the sun in the east; when the sun is at its peak they are parallel to the ground; as the sun sets, they angle toward the west.

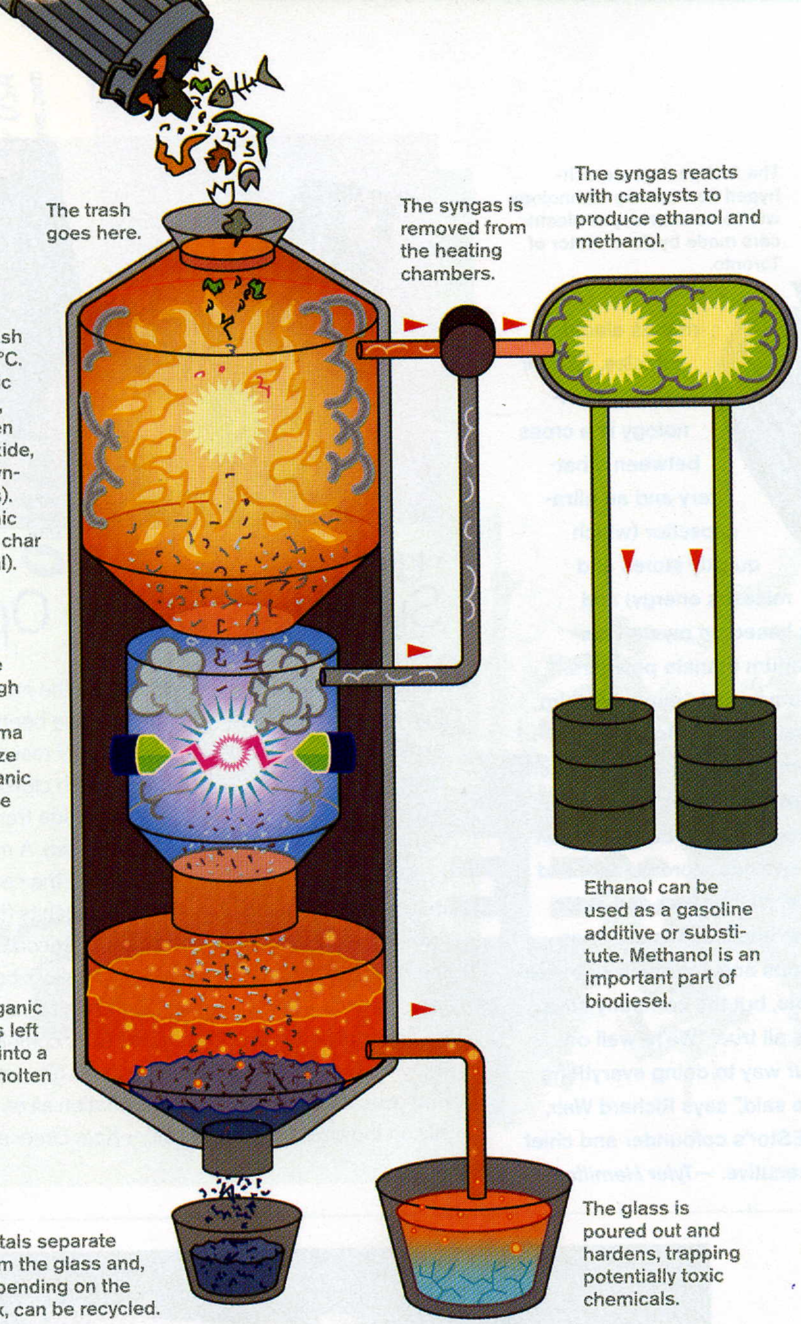
The panels are high enough off the ground for sheep to graze underneath, and the Serpa park will double as pasture for livestock.

The final stages of the solar park's construction included checking the panels' orientation with an inclinometer (below right) and testing the maximum output of the panels. The readout below is a graph of current versus voltage for a string of panels. It tells technicians like Doug Felmann (right) how much of the sunlight striking the solar cells is being converted into electricity.

The plant is designed to operate with no staff on site. Rain will wash the panels occasionally. PowerLight and General Electric will monitor the output of groups of panels over the Internet; PowerLight will dispatch technicians as needed for repairs and once a year for preventive maintenance.

PowerLight is building an even larger plant near Las Vegas this year.





JEFF WEST (GARBAGE); UNIVERSITY OF CINCINNATI (SKIN)

ENERGY

Garbage Power

Forget corn-derived biofuels. Think garbage. The process shown above uses lightning-like arcs of plasma to transform garbage and other waste into gases from which methanol and ethanol can be made. Unlike conventional incineration, it doesn't generate toxic pollutants, and it yields up to six times as much energy as it consumes. Since its fuel—garbage—would be brought to a landfill or incinerator anyway, the technique would avoid the extra energy costs associated with growing and processing corn. The technology, based on research at MIT's Plasma Science and Fusion Center and the Pacific Northwest National Lab in Richland, WA, is now being commercialized by Integrated Environmental Technologies (IET), also in Richland. There's enough energy in U.S. municipal and other waste to replace as much as a quarter of the gasoline the country uses, says Daniel Cohn, cofounder of IET and senior research scientist at the MIT center. IET is in talks with a utility and several municipalities to construct the first such plants, says CEO Jeff Surma. **Kevin Bullis**

The first peek at a much-hyped new battery technology will come courtesy of electric cars made by Zenn Motor of Toronto.

ENERGY

A Battery Beyond Belief?

Is EEStor of Cedar Park, TX, for real? The secretive company announced earlier this year that it plans to begin shipping a 15-kilowatt-hour electrical-energy storage system that can propel a small electric car 322 kilometers and takes just minutes to charge. The first customer: Toronto-based Zenn Motor, which makes electric vehicles. EEStor says its technology is a cross between a battery and an ultracapacitor (which quickly stores and releases energy) and is based on mysterious barium titanate powders. Company documents claim that the new storage system has better energy density than lithium-ion and nickel–metal hydride batteries, that it charges more quickly, and that it's cheaper and safer. The implications are enormous and, for many, unbelievable, but the company says it's all true. "We're well on our way to doing everything we said," says Richard Weir, EEStor's cofounder and chief executive. —*Tyler Hamilton*

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Vinod Khosla

A veteran venture capitalist's new energy

For many years a partner at the blue-blooded venture capital firm of Kleiner Perkins Caufield and Byers, Vinod Khosla has been called the best venture capitalist in the world by both *Forbes* and *Red Herring* magazines. Certainly, he has succeeded more grandly and more reliably, and has failed less spectacularly, than any of his peers. In 2004, he founded Khosla Ventures, which advises entrepreneurs and invests in his latest area of interest: the clean energy technologies that might replace the burning of coal and oil.

***TR:* Whence this newfound preoccupation with clean energy generation?**

Khosla: I enjoy looking at hard, important problems that are still manageable.

Funding new energy technologies has been the work of governments and big businesses. Do you really think energy a good investment for VCs?

Not every energy project can be funded by venture capitalists; some have very long time lines and big budgets. But there are plenty of opportunities that are amenable to a venture approach.

Why are you skeptical about efforts to make coal-based energy generation cleaner and more efficient?

How fast do you think existing energy vendors will move to these clean coal technologies? Alternatives to coal and oil can get here much faster. That said, clean coal is one option for future power generation. We need reliable, predictable power; many people believe that coal can provide that. But concentrating solar power [CSP] is also a real option for large-scale, high-capacity, dispatchable power. Thermal underground storage of heat can be used for utility-grade power generation, too. If large-scale compressed-air energy storage [CAES] works, then wind power will become scalable. So I think there will be a horse race between clean coal with carbon sequestration, wind with CAES, and solar thermal power generation with storage. I think carbon capture and sequestration will be difficult, making clean coal more expensive than CSP. Today, I would put my money on CSP.

What are the benefits of biofuels?

Biodiesel is a good product, but it's nonscalable unless it can be made from biomass instead of seed product. Ethanol is a good start, and it will transition quickly to cellulosic-based production. But I believe new fuels like butanol will come along. I would not be surprised to see biogasoline either, initially made from corn and later from biomass.

When will solar cells, or photovoltaics, be sufficiently efficient to contribute significantly to the globe's energy needs?

Don't equate solar with photovoltaic. I think CSP, leveraging the large investment in traditional, steam-based power generation, and using passive mirrors to concentrate heat, can get to 35 percent efficiency today at $500 per kilowatt. For photovoltaics to compete, we'll need multijunction thin-film solar cells produced with cheap mass-production technologies, and efficiencies above 30 percent.

Does building wind turbines using coal power vitiate their value as an alternative energy?

Many technologies today have long payback periods before the energy invested in them is returned. If it takes so much coal power to produce the solar cell or wind turbine that we are not clean-energy positive for four or five years, is that really a problem? But technology is not static, and all the newer technologies will improve, and the payback period will get faster and faster. These kinds of arguments are generally advanced by proponents of traditional energy and economists who are not used to rapid improvements in technology.

Does nuclear energy have a place in a clean-energy future? After all, France generates 75 percent of its power through nuclear energy.

Nuclear could have a future. That said, I suspect we are unlikely to go to mostly nuclear power in the U.S., because the political and regulatory risks are too high and the time line to build plants is too long. What we really need is to build a big, high-voltage DC power grid, and let nuclear, wind, solar photovoltaics, solar CSP, electricity from biomass and waste, and anything else innovators can think of get on the grid. We need to kick-start the alternatives and let the competitive ones prosper.

Do you believe in the hydrogen economy that President Bush and others have promoted?

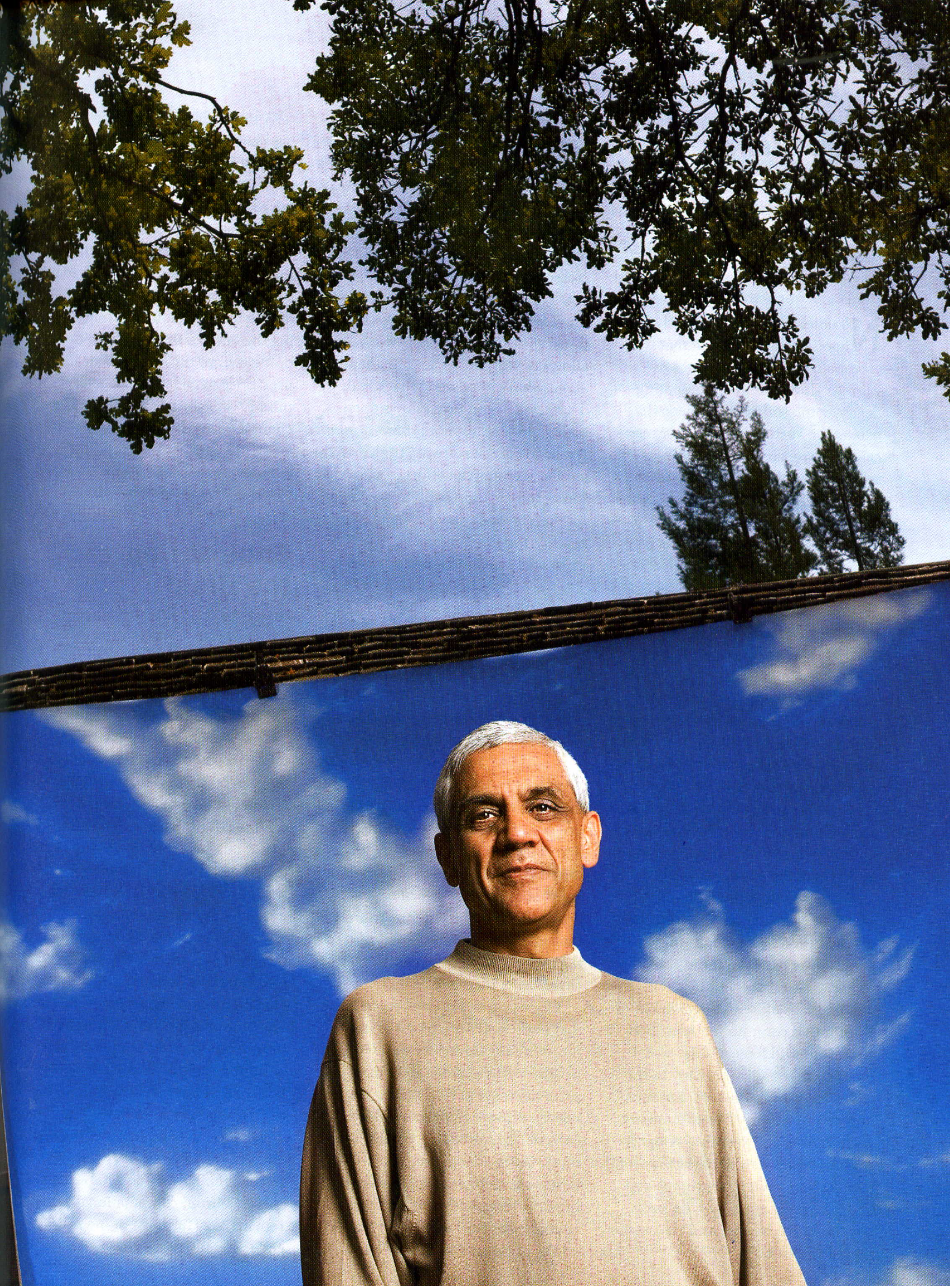
Hydrogen makes no sense to me. There are forces that like any technology that is far enough away that they don't have to make any real changes. We will want to reëvaluate hydrogen in 10 years, but it does not look like a winning option to me today.

Apart from energy, you've also shown some interest in investing in new markets for microloans. Why?

Microloans are the most effective tool in addressing poverty. I am not a big believer in the aid and development programs that big governments favor. But if entrepreneurs use microloans to make biomass an important feedstock, for instance, we will do more to address poverty than all the foreign aid from all the developed world. And biomass can be used to produce fuels, electricity, plastics, and much more.

JASON PONTIN

BART NAGEL



Emerging Technologies 2007

As always, *Technology Review*'s annual list of emerging technologies to watch comprises projects in a broad range of fields, including medicine, energy, and the Internet. Some, such as *optical antennas* and *metamaterials*, are fundamental technologies that promise to transform multiple areas, from computing to biology. Our reports on *peer-to-peer video*, *personalized medical monitors*, and *compressive sensing* reveal how well-designed algorithms could save the Internet, simplify and improve medical diagnoses, and revamp digital imaging systems in cameras and medical scanners. *Nanohealing* and *quantum-dot solar power* demonstrate the potential of nanotechnology to make a concrete difference in our daily lives by changing the way we treat injuries and helping solar energy deliver on its promises. Precise *neuron control* could help physicians fine-tune treatments for brain disorders such as depression and Parkinson's disease. And *single-cell analysis* could not only revolutionize our understanding of basic biological processes but lead directly to predictive tests that could help doctors treat cancers more effectively. Finally, by combining location sensors and advanced visual algorithms with cell phones, *mobile augmented reality* technology could make it easier to just figure out where we are.

DAVE BRADLEY

Nanocharging Solar

Arthur Nozik believes quantum-dot solar power could boost output in cheap photovoltaics. By David Talbot

No renewable power source has as much theoretical potential as solar energy. But the promise of cheap and abundant solar power remains unmet, largely because today's solar cells are so costly to make.

Photovoltaic cells use semiconductors to convert light energy into electrical current. The workhorse photovoltaic material, silicon, performs this conversion fairly efficiently, but silicon cells are relatively expensive to manufacture. Some other semiconductors, which can be deposited as thin films, have reached market, but although they're cheaper, their efficiency doesn't compare to that of silicon. A new solution may be in the offing: some chemists think that quantum dots—tiny crystals of semiconductors just a few nanometers wide—could at last make solar power cost-competitive with electricity from fossil fuels.

By dint of their size, quantum dots have unique abilities to interact with light. In silicon, one photon of light frees one electron from its atomic orbit. In the late 1990s, Arthur Nozik, a senior research fellow at the National Renewable Energy Laboratory in Golden, CO, postulated that quantum dots of certain semiconductor materials could release two or more electrons when struck by high-energy photons, such as those found toward the blue and ultraviolet end of the spectrum.

In 2004, Victor Klimov of Los Alamos National Laboratory in New Mexico provided the first experimental proof that Nozik was right; last year he showed that quantum dots of lead selenide could produce up to seven electrons per photon when exposed to high-energy ultraviolet light. Nozik's team soon demonstrated the effect in dots made of other semiconductors, such as lead sulfide and lead telluride.

These experiments have not yet produced a material suitable for commercialization, but they do suggest that quantum dots could someday increase the efficiency of converting sunlight into electricity. And since quantum dots can be made using simple chemical reactions, they could also make solar cells far less expensive. Researchers in Nozik's lab, whose results have not been published, recently demonstrated the extra-electron effect in quantum dots made of silicon; these dots would be far less costly to incorporate into solar cells than the large crystalline sheets of silicon used today.

To date, the extra-electron effect has been seen only in isolated quantum dots; it was not evident in the first prototype photovoltaic devices to use the dots. The trouble is that in a working solar cell, electrons must travel out of the semiconductor and into an external electrical circuit. Some of the electrons freed in any photovoltaic cell are inevitably "lost," recaptured by positive "holes" in the semiconductor. In quantum dots, this recapture happens far faster than it does in larger pieces of a semiconductor; many of the freed electrons are immediately swallowed up.

The Nozik team's best quantum-dot solar cells have managed only about 2 percent efficiency, far less than is needed for a practical device. However, the group hopes to boost the efficiency by modifying the surfaces of the quantum dots or improving electron transport between dots.

The project is a gamble, and Nozik readily admits that it might not pay off. Still, the enormous potential of the nanocrystals keeps him going. Nozik calculates that a photovoltaic device based on quantum dots could have a maximum efficiency of 42 percent, far better than silicon's maximum efficiency of 31 percent. The quantum dots themselves would be cheap to manufacture, and they could do their work in combination with materials like conducting polymers that could also be produced inexpensively. A working quantum dot–polymer cell could eventually place solar electricity on a nearly even economic footing with electricity from coal. "If you could [do this], you would be in Stockholm—it would be revolutionary," says Nozik.

A commercial quantum-dot solar cell is many years away, assuming it's even possible. But if it is, it could help put our fossil-fuel days behind us.

Reviews

Books, artifacts, reports, products, objects

AUTOMOTIVE TECHNOLOGY

Hell and Hydrogen

No matter how well they're engineered, hydrogen cars offer no real answer to the imminent threats posed by global warming.

By David Talbot

By the time Klaus Draeger, BMW's manager of research and development, took the microphone at a Berlin hotel last fall, the assembled journalists' bellies were full of mint juleps—and it all started to make sense. Maybe the world's oil crisis and the threat of climate change could be sensibly addressed by using hydrogen as a transportation fuel. Draeger sketched the alluring vision of a future in which high-performance luxury cars burn hydrogen and emit mostly water vapor. The hydrogen could someday be provided by renewable sources of energy, he said, and nobody would have to make any sacrifices. And we journalists would get to drive the first such cars the following day.

"You'll be pioneers! You will be sitting at the wheel of the Hydrogen 7, driving through Berlin and the countryside. And for the first time, you will drive this hydrogen-powered luxury saloon," Draeger exclaimed, using the Britishism for "sedan." BMW will lend 100 of these cars to yet-unnamed public figures as part of its global clean-energy promotional campaign. In some ways, the campaign resembles GM's effort to tout its own hydrogen-car program. GM's focus is on a futuristic fuel-cell car. The BMW version uses internal combustion: it burns hydrogen rather than skimming off its electrons. Same message, though: hydrogen is the answer.

"Experts will tell you that hydrogen has the biggest possibility to replace fossil fuels," Draeger explained, as the wine flowed. "Please see the Hydrogen 7 as an offer. We can only make this car a reality with our partners in political science, the world of business, the energy industry." He concluded with an appeal to "politicians the world over" to make the production, delivery, and storage of clean hydrogen affordable.

HYDROGEN 7
BMW

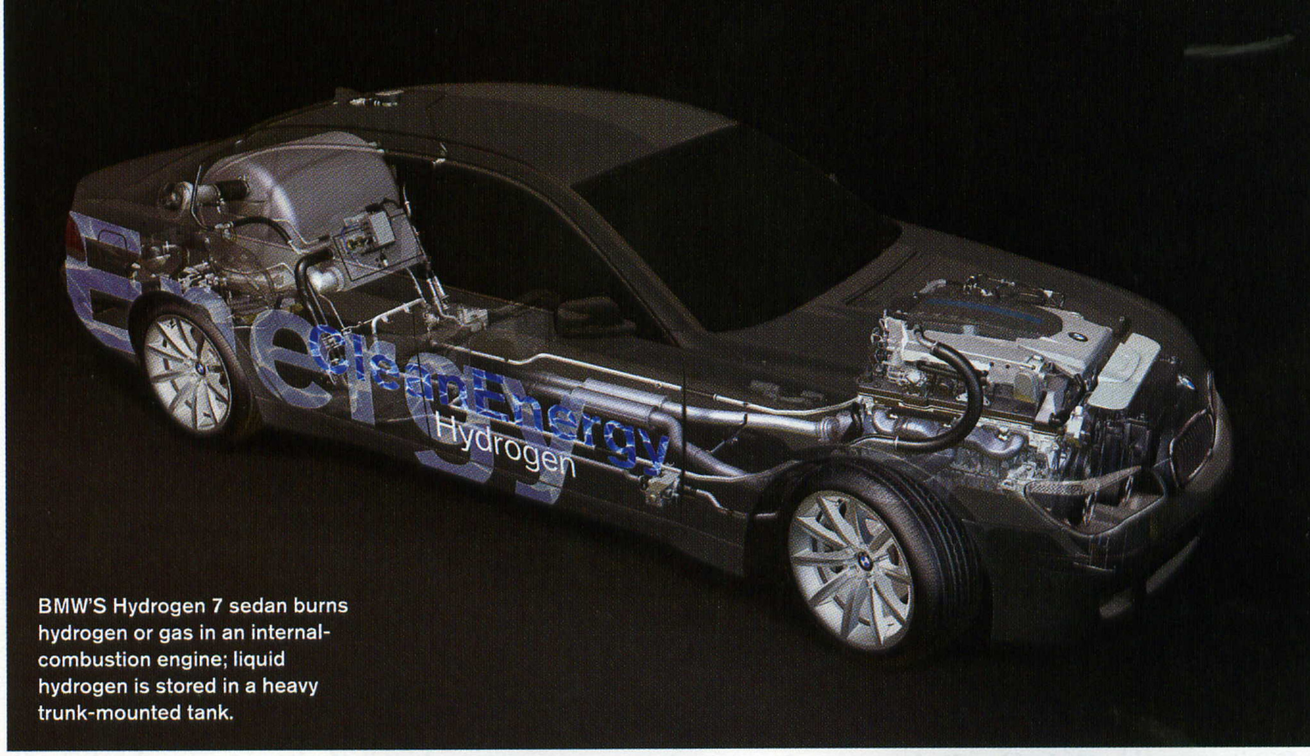
HELL AND HIGH WATER: GLOBAL WARMING—THE SOLUTION AND THE POLITICS—AND WHAT WE SHOULD DO
By Joseph J. Romm
William Morrow, 2007, $24.95

The next day, I got a look at the Hydrogen 7. From the outside it looked like a normal BMW four-door luxury sedan. I opened the trunk and marveled at the heavy steel tank that held liquid hydrogen at –253 °C. While driving, I touched a button on the steering wheel to switch from gasoline to hydrogen; I noted no hiccup, just a higher-pitched engine noise. The car is very nice. But does it make environmental sense?

The simple answer is no. In the context of the overall energy economy, a car like the Hydrogen 7 would probably produce far more carbon dioxide emissions than gasoline-powered cars available today. And changing this calculation would take multiple breakthroughs—which study after study has predicted will take decades, if they arrive at all. In fact, the Hydrogen 7 and its hydrogen-fuel-cell cousins are, in many ways, simply flashy distractions produced by automakers who should be taking stronger immediate action to reduce the greenhouse-gas emissions of their cars. As of 2003, transportation emissions accounted for one-third of all U.S. carbon dioxide emissions.

Nobody has made this point more clearly than Joseph Romm does in *Hell and High Water*. Romm is an MIT-trained physicist who managed energy-efficiency programs in the U.S. Department of Energy during President Clinton's administration and now runs a consultancy called the Center for Energy and Climate Solutions. His book provides an accurate summary of what is known about global warming and climate change, a sensible agenda for technology and policy, and a primer on how political disinformation has undermined climate science. In his view, the rhetoric of "technology breakthroughs"—including the emphasis by President Bush and some in the auto industry on a future hydrogen economy—provides little more than official cover for near-term inaction.

Romm reminds us of the growing scientific consensus: we must quickly reduce greenhouse-gas emissions to avoid the worst effects of global warming. Therefore, Romm argues, the job of political leaders is clear. Among other things, they must rapidly adopt tighter



BMW'S Hydrogen 7 sedan burns hydrogen or gas in an internal-combustion engine; liquid hydrogen is stored in a heavy trunk-mounted tank.

efficiency standards for homes, offices, and industry; mandate strict increases in automobile fuel economy, which means widespread adoption of ultra-efficient cars, including hybrids; and build as many wind and solar plants as possible, while cautiously expanding nuclear power. Romm even argues that we could cut nationwide carbon dioxide emissions by two-thirds without increasing anyone's annual electric bill. He cites California's three-decade record of aggressive investment in cleaner energy technologies and energy-efficiency programs. When these investments are amortized, costs stay flat while power consumption and carbon dioxide emissions plunge. Today, Romm writes, a Californian has an electric bill no larger than the average American's but generates just one-third the carbon dioxide.

The reason hydrogen-powered cars would produce more carbon dioxide emissions than regular cars starts with the fact that it takes energy to create hydrogen. One way to produce hydrogen is to extract it directly from fossil fuels; indeed, a 2004 National Academy of Sciences study predicted that fossil fuels would be the main source of hydrogen for "several decades." The other way is to split water molecules using electricity. Naturally, BMW talks up this approach, envisioning electricity that would ultimately be supplied by renewable sources. BMW brochures feature the Hydrogen 7 parked in front of wind turbines and shiny photovoltaic arrays. But renewable sources furnish only 2 percent of the world's electricity (not counting hydropower's 16 percent). Coal, by contrast, supplies 39 percent–and is the worst emitter of carbon dioxide, watt for watt. Clearly, a great use for renewable power is to replace coal power. But is it worthwhile to divert even a small part of it to the task of manufacturing hydrogen?

According to Romm's analysis, the math for hydrogen cars simply doesn't work out. Burning coal to generate one megawatt-hour of electricity produces about 2,100 pounds of carbon dioxide. It follows that one megawatt-hour of renewable power can avert those emissions. Using that electricity to make hydrogen would yield enough fuel for a fuel-cell car to travel about 1,000 miles, Romm says. But driving those 1,000 miles in a gasoline-powered car that gets 40 miles per gallon would produce just 485 pounds of carbon dioxide. In this sense, Romm says, a vehicle powered by hydrogen fuel cells would indirectly create four times the carbon dioxide emissions of today's most efficient gasoline cars.

And the numbers for the Hydrogen 7 are worse, because it *burns* hydrogen. Combustion produces thrilling torque, but it's far less efficient than fuel-cell technology. Also counting against the Hydrogen 7 is the fact that it stores hydrogen as a liquid; chilling hydrogen and compressing it into liquid form consumes more energy than storing it as a compressed gas. "It's safe to say this is a pointless activity," Romm says. "BMW has managed to develop the least efficient conceivable vehicle that you could invent."

BMW's new car is a marvelous piece of engineering. But it is also a distraction from the real issues: we must burn less fossil fuel and reduce our greenhouse-gas emissions today. Innovative automakers like BMW should turn their remarkable skills to making cars that are more efficient–such as BMW's new 118d economy hatchback, which on average gets 50 miles to the gallon. But the Hydrogen 7 is hardly the "new standard of sustainable pollutant-free mobility" that BMW proclaims. Draeger's offer is one we would be wise to refuse. TR

David Talbot is Technology Review*'s chief correspondent.*

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