As calls for energy independence increase, Rensselaer alumni explore innovative solutions.

THE **FUTURE** OF ENERGY

WITH RISING OIL AND GAS PRICES making front-page news and stretching the budgets of many Americans, and as evidence for global warming mounts, a national debate on the future of energy has been ignited in the United States, re-energizing the search for viable alternatives and "green" solutions.

In his State of the Union address at the end of January, President Bush called for cleaner, cheaper, and more reliable alternative energy sources, saying that "America is addicted to oil," and that the best way to break this addiction is through technology.

Steve Percy '68, former chairman and CEO of BP America, agrees.

"Coming up with new technologies will be key to the acceptability and access of new energy sources," says Percy, who also served as the head of Phillips Petroleum's Refining, Marketing and Transportation Company. "A lot of people would say that technology is part of the problem, and I would say that it's got to be the solution. It's about how we can continue to improve our living standards with less environmental impact."

And, no energy source alone will be able to solve all our energy needs, Percy and other energy experts say. "There's no silver bullet. We're going to need help just about everywhere we can find it," he says.

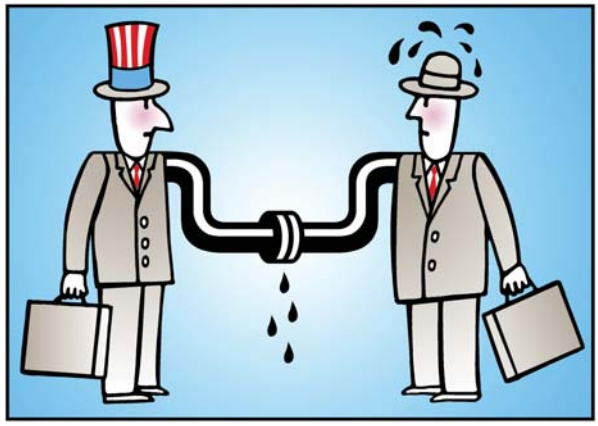
Percy is one of a number of Rensselaer alumni who have been at the forefront of energy innovation, developing and promoting new technologies and research, shaping policy, and establishing successful businesses in the renewable energy market.

At the same time, Rensselaer has re-energized its research commitment to energy security, hiring faculty and administrators who are visionaries at the top of their fields and establishing new centers and programs.

BY JODI ACKERMAN FRANK

In the past 35 to 40 years, worldwide energy consumption has nearly doubled, driven by population growth, rising living standards, invention of energy-dependent technologies, and consumerism. Electricity use has nearly tripled. If these trends continue, global energy consumption will double again by mid-century.

Compounding the threat of global warming are the **RISING CONCERNS OF WORLD ENERGY SHORTAGES** fueled by growing demand, **AN INCREASINGLY VOLATILE POLITICAL WORLD**, the succession of hurricanes in the Gulf of Mexico in 2005 that knocked out oil production for months, and evidence of a global depletion of petroleum resources.



A CHANGE IN THE WEATHER It is 2010. The world is experiencing an increasingly volatile climate with disastrous consequences. While temperatures in Africa and Asia exceed 90 degrees for days at a time, blistering cold weather plagues much of Europe, North America, and Canada. Violent hurricanes are commonplace in Central America and the Caribbean. Drought persists in agricultural regions in Europe and in eastern North America.

The abrupt climate changes take their toll as famine, disease, and weather-related disasters destabilize the geopolitical environment, eventually leading to armed conflict over food, clean water, and energy supplies.

A far-fetched scenario? Perhaps. But Peter Schwartz '68 points out that recent scientific findings on global warming and its effects on climate change suggest that the world could be on the cusp of such a cataclysmic event.

"There is an urgent need to make a huge change [in our energy strategy]," says Schwartz, an internationally renowned futurist and business strategist who formerly headed scenario planning at Royal Dutch/Shell Group.

Schwartz was co-author of the Pentagon-sponsored report released in late 2003 that posited this scenario. Built on the research of leading climate experts, the report revitalized the global warming debate in Congress.

"The findings raised the sense of urgency of the climate-change issue. Our research, sponsored by the Pew Center on Climate Change, concluded that the main leverage is in reducing fossil-fuel burning, especially coal," Schwartz says.

Compounding the threat of global warming are the rising concerns of world energy shortages fueled by growing demand, an increasingly volatile political world, the succession of hurricanes in the Gulf of Mexico in 2005 that knocked out oil production for months, and evidence of a global depletion of petroleum resources. Some energy experts suggest that traditional oil production will reach its peak within the next two decades and then plummet in an irreversible decline.

"I think the [oil production] system is starting to show that there is going to be a resource crunch sometime in the next 15 or 20 years," says Percy.

Economic prosperity depends upon energy. Power is essential to producing food and a variety of everyday products, and to running automobiles, mass transit systems, homes, industries, offices, hospitals, stores, and the many other building blocks of a vibrant economy. In general, fossil fuels—coal, oil, and natural gas—provide more than 85 percent of all the energy consumed in the United States, according to the Department of Energy (DOE). But oil is really the lifeblood of America's economy, supplying more than 40 percent of the U.S. total energy demands and nearly 100 percent of fuel for transportation.

Still, Percy says we're not in an oil crisis just yet. "Obviously, the world economies have been able to absorb the much higher prices and seem to be growing fine," he says.

Percy also shares Schwartz's sense of urgency in addressing global warming by cutting the use of fossil fuels, which release heat-trapping carbon dioxide and other pollutants. Percy, who co-chaired the Climate Change Task Force under President Bill Clinton's Council on Sustainable Development, was an author in a recently published United Nations report on the state of the world's ecosystems. The report, called the Millennium Ecosystem Assessment, involved nearly 1,500 scientists worldwide.

"It was really about assessing the state of the planet. The bottom line was that the global ecosystems are under tremendous pressure and as the world economy continues to expand—as we hope it does because there are so many impoverished people—that stress will grow and that stress is both a threat and an opportunity for business," he says. "The threat is obviously of potential regulation or making it difficult to obtain raw materials. But on the other hand, those who have new technology to help solve some of these problems will have great opportunity."

THE POWER OF WIND Although renewable energy sources are a tiny fraction of the world's power supply, providing about 2 percent of the primary energy used, they are increasingly becoming an important solution to clean and affordable energy. Wind, in particular, has become the world's fastest-growing power source, according to DOE. General Electric, which bought bankrupt Enron's wind assets in 2002, expects to sell $8 *billion* worth of wind turbines in 2006 and 2007 globally.

"We're sold out," says Victor Abate '86, vice president for renewables at GE. "We're going to ship more than 2,100 wind turbines this year alone."

Today's highly efficient industrial-grade wind turbines are a far cry from the old-fashioned windmills that once pumped water for farms. Some farms use the big industrial-grade wind turbines that Abate talks about. Each turbine has a generator the size of a mobile home that sits on top of a tower, which typically reaches 240 feet high. The generator is driven by a set of three blades that spans 100 meters in diameter, the length of a football field. Built mostly on farmland, coastal areas, and in the ocean, each turbine produces from 1.5 megawatts up to 3.6 megawatts of energy, enough to power about 2,000 homes.

"The world wants this," Abate says. "For every wind turbine you install, you offset natural gas, oil, and coal. There are no carbon emissions. Wind energy is clean."

The global installed base for wind is expanding at a rate of about 17 percent a year, according to Abate, and rapid worldwide growth is projected to continue as more countries turn to wind.

In the U.S., some 28 states now have wind farms that feed electricity into the local grid. Many of these states have incorporated renewable portfolio standards (RPS), which require a certain amount of electricity to come from

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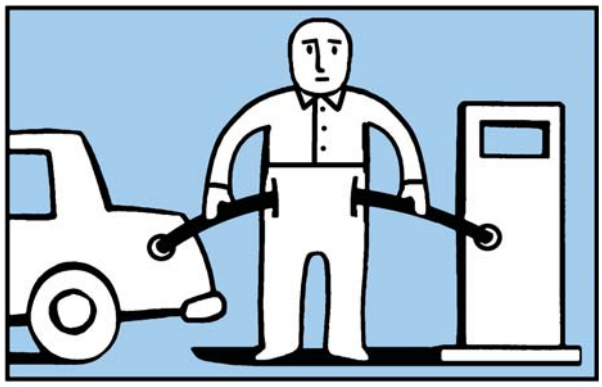
In general, fossil fuels—coal, oil, natural gas—provide more than 85 percent of all the energy consumed in the United States. But **OIL IS REALLY THE LIFEBLOOD OF AMERICA'S ECONOMY,** supplying more than 40 percent of the U.S. total energy demands and **NEARLY 100 PERCENT OF FUEL FOR TRANSPORTATION.**



renewable sources. New York's RPS calls for 24 percent of the state's electricity to come from renewable sources by 2013. In Arizona, that figure is 15 percent by 2025, and in California it's 20 percent by 2010.

"If you look at the RPSs in place today, they're driving about 22 gigawatts of renewable investment over the next several years. Each gigawatt is about $1 billion worth of business," says Abate. "That's driving a lot of these wind farms, and a lot of investment in renewables in general."

SOAK UP THE SUN Solar power also is sparking new hope as a reliable green energy source. This year, it is expected to be a $9 billion industry, according to Dan Shugar '86.

Shugar has turned the sun's rays into a commercially viable energy source, with his company, PowerLight, a designer, manufacturer, and installer of large-scale solar electric systems, based in Berkeley, Calif.

Shugar is a Californian whose day-to-day life is all about soaking up the rays. He drives an electric car, powered exclusively by the sun. When he gets to work, he'll plug it into his company's commercial building, which also is solar-powered.

"By midmorning, my car will be fully charged," Shugar says on a recent morning as he made the 25-mile trip from home to work. "I have 46,000 miles on this car and I haven't put a drop of gas in this thing. That's cool, don't you think?"

For the last five years, PowerLight has been ranked as one of the fastest-growing private corporations in the country by *Inc.* magazine. As a result, PowerLight recently was listed in the Inc. 500 Hall of Fame, a distinction shared with companies such as Microsoft and Oracle.

In 2004, Shugar's company completed the world's largest solar power system in Germany. Ground-mounted solar panels cover an area the size of 45 football fields, providing power to three nearby towns. PowerLight also specializes in installing solar panels on flat commercial rooftops. The company has expanded into the residential market, providing integrated solar solutions for homebuilders.

The cost to buy and install solar panels is a tenth of the price it was 25 years ago. And, with new thin films and other technologies, the panels provide twice as much energy as they did a decade ago, from 10 percent to 20 percent efficiency.

"That doesn't sound like a lot, but let me give you some context. The gasoline in your car operates at only about 15 percent efficiency," Shugar says.

At this point, solar generation doesn't eliminate the need for the power utility and probably won't be the top energy source to replace oil anytime soon, Shugar says.

But, it is sure to bring much-needed relief to the overworked electric grid to prevent rolling blackouts like those experienced in southern California during the warmest times of year when farmers are drawing extra power to irrigate their fields and utility customers are cranking air conditioners, constraining already-overloaded lines.

With its compatibility with the electric grid and its modularity—you can put a few panels on a rooftop or add thousands to service whole communities—solar power generation is an ideal source of distributed energy, which is essentially supplementing electricity to a main power district.

Solar panels can be placed alongside power line transformers, where the sun-generated energy can be fed into the grid. The electricity from the same panels on your roof can also supply power to the local grid.

Shugar has been a leader in promoting the concept of net metering, which allows customers to sell excess energy back to the utility company at retail value.

Shugar's integral role in pushing net metering requirements in some states, including California, has spurred a boom in consumer investment in solar and other renewable energy sources.

A WASTE-FULL APPROACH Biomass—plant matter and byproducts including crops, wood waste, and animal manure—is another promising renewable energy source. The gasoline supplement ethanol, derived from corn, is probably the most familiar biofuel.

Many more biomass technologies are on the verge of being developed that turn everything from rice to aquatic plants into energy. One endless source of power that researchers have had their eye on is literally dumped down the toilet everyday.

Bruce Logan '79, the Kappe Professor of Environmental Engineering at Penn State University, is leading a research team that has developed a microbial fuel cell that uses bacteria to break down organic matter in sewage to generate electricity. The process cleans up wastewater at the same time.

Logan is working to make the device commercially available within the next three to five years. The immediate application is to use the fuel cells in conjunction with wastewater treatment plants to offset the costs of running the facilities. But, wastewater alone will not solve the energy crisis, Logan says.

"It is hoped that, as these technologies evolve, they will become useful techniques for producing energy from a variety of organic matter sources," he says.

Hydrogen, the most abundant element in the universe, also has its promoters as the next great energy revolution. But the gas must be extracted using other energy sources. Currently, hydrogen is commercially produced primarily from fossil fuels, a situation that will have to change, says Logan, for it to be a truly green and sustainable energy source.

Logan has found a way to use bacteria to extract hydrogen from wastes. The hydrogen can then be used in conventional fuel cells to make electricity.

By modifying the microbial fuel cells so that

ECONOMIC PROSPERITY depends upon energy. **POWER IS ESSENTIAL** to producing food and a variety of everyday products, and to running automobiles, mass transit systems, homes, industries, offices, hospitals, stores, and the many other **BUILDING BLOCKS OF A VIBRANT ECONOMY.**

they do not use oxygen, his team has developed the first process that enables bacteria to coax four times as much hydrogen directly out of biomass than can be generated by fermentation alone. To allow the bacteria to extract the extra hydrogen, Logan assists the microorganisms with a power boost, which is a fraction of the voltage needed to electrolyze water in producing hydropower.

Logan has won a number of awards for his research. Recently, he was named a winner of the Popular Mechanics 2005 Breakthrough Award.

NUCLEAR—A VIABLE OPTION With accidents at Three-Mile Island and Chernobyl a part of recent history, nuclear power remains controversial, but with global awareness of the dangers of fossil fuels, enthusiasm for nuclear fission as an abundant, emission-free power source is reviving.

"Around the world nuclear power has been steadily growing," says Chauncey Starr '32, the Rensselaer Alumni Hall of Fame member who introduced the world to nuclear power for peaceful purposes. After working on the Manhattan Project, Starr founded the first nuclear power companies in the U.S., France, and Germany. In 1990, he received the National Medal of Technology from President George Bush for his contributions to nuclear power, including his seminal work in risk analysis.

Nuclear fission is the second largest source of electricity in the U.S., supplying about 20 percent of the nation's electric use each year. In other countries, that number is much higher. For example, nuclear provides more than 75 percent of the electricity in France. In addition, China, Japan, and other countries are building new reactors.

In particular, there is renewed interest in "recycling" the spent fuel in which the recovered plutonium and uranium can be used to generate more energy. When fuel assemblies are removed from the reactor for the first time, this "spent fuel" contains over 95 percent of its original energy potential.

"When we talk about nuclear power being good for thousands of years, it's because it takes very little of the original uranium to produce a huge amount of energy, if it's recycled," Starr says.

Over the years, accidents, waste storage, and concerns of weapon proliferation have kept nuclear power from playing a greater role. But, Starr notes, great strides have been made in developing more efficient reactor designs as well as improved regulations for both plant safety and to prevent weapons proliferation.

As far as where to dispose of the radioactive waste, Starr says storing it deep underground is a safe solution, adding that the amount of waste is a small fraction of what is produced by fossil fuels and that the radioactive activity eventually becomes negligible.

"If condensed into a pill, the ashes that would be left of the nuclear power it takes to service a single individual in his or her lifetime in our society would represent two aspirins. So, you're dealing with an extremely small amount of waste," he says.

Nuclear energy is one of the most viable options for clean energy, says Starr, who wrote a landmark paper in 1969 on how to weigh the risks and social benefits of various technologies.

"We look for the benefits of living on a day-to-day basis. We look for comfort, good health, physical security. We look for a stable society, and we want all that science and technology can give us," he says. "To do all that, society takes a risk. If you're not a society that's willing to stick its neck out and try new things, you're not going to progress. Nuclear power represents a living example of that."

Rensselaer President Shirley Ann Jackson also believes nuclear power is having a resurgence. "This is being achieved through safer and more economical performance of nuclear power plants, and by technological innovations in new designs—which address safety and profitability concerns, and which are targeted to deal with issues of nuclear waste," says Jackson, former chairman of the Nuclear Regulatory Commission. Some American companies are planning for this nuclear future. "Several U.S. utility companies already are identifying potential new plant sites and testing new federal licensing processes for advanced-design nuclear power plants. The industry anticipates building 12 to 15 new nuclear plants by 2015," she adds.

CLEAN COAL Out of all the fossil fuels, coal can be the dirtiest. It also is the cheapest and the most plentiful. The U.S. alone has enough coal to last more than 200 years at today's level of energy use, according to DOE.

"Those of us who can figure out how to burn coal with minimal pollution will be part of the 'energy-environment economic' solution," says Robert Hanfling '59, a clean-coal proponent and an energy policy expert who has served under three U.S. presidents.

The Brooklyn native remembers what it was like living in the midst of dirty and inefficient power plants 50 years ago. "You've heard the commercial, 'ring around the collar?' Well, when I was growing up in the '40s and '50s, if you wore a white shirt, by the time you came home you had ring around the collar," Hanfling recalls. "The incinerators and the furnaces in apartment buildings were burning coal or burning trash, and the soot was all over the place."

Hanfling is much more optimistic about coal power these days. He heads KFx Inc., a company in Denver, Colo., that has developed a way to process coal into a cleaner, more energy efficient product called "K-Fuel."

"It is the unleaded gasoline equivalent for the coal-fired industry," Hanfling says.

The process uses temperature and pressure to reduce the water content of low-grade coal and lignite, thereby increasing the energy content in Powder River Basin coal by about 30 percent. In removing the water, Hanfling adds, the process also reduces the mercury content by 70 percent and upon combustion reduces sulfur and nitrogen oxide emissions by 30 percent.

The company plans to construct facilities with a total capacity of 50 million tons per year of K-Fuel product within the next five years.

TOWARD A NEW ENERGY SYSTEM The federal government has been called upon by many in the field to play a greater role in pushing the frontiers of a greener energy system. Public incentives such as tax credits for using more efficient vehicles, regulation, and supporting industry with funding in developing alternative strategies are important first steps, Hanfling and others say.

"Energy is a key part of our national security. We pour billions of dollars into our defense department, yet we put relatively little money into energy security," Hanfling says.

Hanfling also believes that raising prices, particularly at the pump because vehicles consume nearly half of all crude oil, will shift consumer behavior toward conservation and more energy-efficient alternatives.

Percy says higher energy prices, particularly in the form of taxation, and regulations such as a cap-and-trade policy on carbon emissions will spur the technological innovation necessary to make a dependable energy transition.

The trend of higher energy costs is not likely to reverse anytime soon, Schwartz says. In the best-case scenario, the world makes a fairly smooth transition to a cleaner, more efficient energy system, which entails higher energy prices. "By the middle of the century, energy will be cleaner, greener, but more expensive," he says.

While Schwartz says he generally is not a supporter of the President's energy policy, "I find myself in near total agreement with the new initiatives he announced in his State of the Union, particularly recognizing the diversity of energy resources we need, from renewables to nuclear to clean coal," he says. "The major criticism I have is the failure to address the demand for transport fuels either with higher mileage standards or a much higher gasoline/carbon tax. In the absence of such measures, we are unlikely to reduce demand by much."

Still, Schwartz is optimistic that America and the rest of the world are beginning to look toward the greener side.

Abate shares that optimism and also the deepening concern of what it may mean if we take a wrong turn. "The industry is changing. It's around sustainability. If you don't get your energy policy right, your great-grandkids are going to live worse than you did."

Energy Initiatives at Rensselaer

In the past 35 to 40 years, worldwide energy consumption has nearly doubled, driven by population growth, rising living standards, invention of energy-dependent technologies, and consumerism. While coal usage has decreased marginally, consumption of every other major energy source has increased markedly. Electricity use has nearly tripled. If these trends continue, global energy consumption will double again by mid-century.

"As the global demand for energy increases, it is crucial that we develop alternative and renewable energy sources," says Omkaram "Om" Nalamasu, vice president for research. "Rensselaer's combination of research, education, and entrepreneurship provides novel opportunities to move new energy technologies from the lab to the market." Here's a look at what Rensselaer is doing:

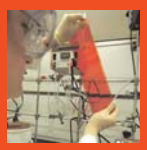
Center for Future Energy Systems

This $20 million research center, in partnership with Cornell University and Brookhaven National Laboratory, seeks to meet the energy challenges of the 21st century by focusing on innovation in and commercialization of energy conservation and renewable energy systems.

Center for Fuel Cell and Hydrogen Research

Rensselaer's Center for Fuel Cell and Hydrogen Research focuses on fuel cell development, hydrogen generation and storage, electrochemistry, solid state and polymer science, and the application of nano-materials in fuel cell and hydrogen research.

Fuel Cell Research Education



Rensselaer has initiated a $4.8 million novel interdisciplinary program to train doctoral students in fuel cell science and engineering. The program is supported by a $3.2 million, first-of-its-kind fuel cell research education grant from the National Science Foundation combined with a $1.6 million investment by Rensselaer.

Center for Power Electronics Systems

Established in August 1998, the Center for Power Electronics Systems is one of the nation's relatively few National Science Foundation Engineering Research Centers. Its vision is to provide the nation with the capabilities to become a world leader in power electronics.

Future Chips Constellation

The Future Chips Constellation focuses on innovations in materials and devices, in solid-state and smart lighting, and will extend to applications such as sensing, communications, and biotechnology.

New York State Center for Polymer Synthesis

Researchers are designing new polymers that could revolutionize or create entirely new industries. The future implications of this research are limitless, from achieving plug-in power for fuel cells, to biomedical applications that could help diagnose and treat many diseases.

Lighting Research Center

Rensselaer's Lighting Research Center (LRC) is the leading university-based research center devoted to lighting. The center programs cover a range of activities including both laboratory testing of lighting products and real-world demonstration and evaluation of lighting products and designs. The LRC conducts research into energy efficiency, new products and technologies, lighting design, and human factors issues.