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CLEAN ENERGY SOLUTIONS

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ECONOMIC PERSPECTIVES

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CLEAN ENERGY SOLUTIONS

INTRODUCTION

In the first decade of this new century, clean energy technologies are transforming the way we power our homes, our businesses, and our vehicles. Before the decade is out, I believe we will see even more dramatic breakthroughs.

This isn't just my opinion as U.S. secretary of energy: Clean energy is gaining momentum in the global marketplace as well.

Venture capitalists are investing hundreds of millions of dollars in alternative energy technologies. The Ardour Global Index of renewable energy companies began operating in May 2006. The investment community clearly believes money can be made in renewable energy, which is just another sign that renewable energy is on the verge of a major market expansion.

In short, the case for "green" energy is as strong as it has ever been.

President Bush's Advanced Energy Initiative seeks additional funding for clean energy technologies, beginning with a 22 percent increase in 2007. The United States is accelerating its research into technologies that we believe hold the greatest promise to be competitive in the marketplace.

Clean energy systems are incredibly diverse, yet technology has brought them within our grasp. Cellulosic ethanol, hydrogen fuel cells, next-generation nuclear power, photovoltaic solar cells, and near-zero-emissions coal plants will transform the way the economies of the world are powered to more clean, alternative sources of energy.

As the various articles in this journal explain, these new technologies promise to raise standards of living around the world and are giving us the tools to build a brighter, cleaner, and more prosperous future. I hope you will find these essays to be as interesting and informative as I have.

Samuel W. Bodman
U.S. Secretary of Energy

CLEAN ENERGY FOR TOMORROW

Paula Dobriansky

The world needs affordable and clean energy to fuel economic growth, development, and democracy without harming the environment. The United States is confronting this challenge with transformational technologies, creativity of entrepreneurs, and support for local initiatives in the developing world.

***Paula Dobriansky** is Under Secretary of State for Democracy and Global Affairs.*

AP/Wide World Photo

President Bush talks about energy at the California Fuel Cell Partnership laboratory.

Ensuring access to ample, affordable, clean, and sustainable sources of energy is unquestionably one of the greatest challenges facing the modern world. The U.S. government and America's private sector and nongovernmental organizations are confronting it by building on a long tradition of clean energy research to develop transformational technologies that will reduce our reliance on oil and have far-reaching benefits for the entire world.

By embracing the energy challenge, the United States is working to promote energy security, reduce poverty, reduce harmful air pollution, and address climate change. These efforts often strengthen self-governing societies by building a culture of democracy at the grassroots level.

The Energy Challenge

Rarely does a day pass without an energy-related issue making the headlines. Whenever world leaders meet, energy is an important and urgent topic of discussion. From the 2002 World Summit on Sustainable Development to the 2005 Gleneagles Group of Eight (G8) Summit to the 2005-2007 energy cycle of the UN Commission on Sustainable Development, energy is front and center.

And for good reason. Supply disruptions and rising prices loom large in day-to-day decisions about how we fuel our vehicles, heat our homes, and power our businesses. What's more, approximately 2 billion people—nearly one-third of the world's population—lack access to the modern energy services that are essential for bringing schools into the 21st century, driving industry, moving water, and boosting crop production, as well as for lighting, heating, and cooling health facilities.

The integrated goals of energy security and poverty alleviation are also inextricably linked with the need to reduce harmful air pollution and address climate change. The World Health Organization estimates that 4,400 people die every day from indoor air pollution, much of which is associated with unhealthy cooking and heating practices.

Developing Clean and Affordable Energy Technologies

The United States believes that the best way to promote energy security and help nations develop, while protecting the environment and improving public health, is to promote clean and affordable energy technologies. We will need a diversified approach that includes conventional, advanced, and renewable energy and energy-efficiency technologies.

The U.S. government, frequently in partnership with the private sector, is pursuing both domestically and internationally a suite of technologies that should be incrementally deployed by the second half of this century. These include new biofuels from nonfood crops; clean coal technology; commercialization of plug-in hybrid autos; hydrogen fuel cell technology; more efficient, proliferation-resistant nuclear systems; and fusion technology. And these are just the highlights.

In his January 2006 State of the Union address, President George W. Bush outlined a strategy to reduce America's dependence on oil. The president's Advanced Energy Initiative proposes a 22 percent increase in funding for clean energy research at the U.S. Department of Energy. This includes greater investment in solar and wind technologies, zero-emission coal-fired power plants, clean nuclear technology, and ethanol.

It is important that we not only develop clean energy technologies but also work to make them more affordable and accessible. That is why the U.S. government has spent more than $11.7 billion since 2001 to develop alternative energy sources. This funding has contributed to a dramatic reduction in the cost of renewable energy. As the costs of conventional energy rise, the private investment community is responding. In 2005, we saw $44 billion of new capital investment in renewable energy technologies in the electricity sector. Renewables now comprise approximately 20 to 25 percent of global power sector investment.

As we strive to develop new sources of energy, we are also working hard to reduce our energy consumption. A leading example of this effort is Energy Star, a U.S. government-backed program that helps businesses and individuals protect the environment through superior energy efficiency. With the help of Energy Star, Americans saved enough energy in 2005 alone to avoid greenhouse gas emissions equivalent to those from 23 million cars—all while saving $12 billion on their utility bills, or 4 percent of the United States' total annual electricity demand.

Disseminating Technologies Through Public-Private Partnerships

Multi-stakeholder partnerships with governments, civil society, and the private sector are critical to addressing the energy challenge. The United States participates in a broad spectrum of partnerships, with groups ranging from small American nongovernmental organizations building and demonstrating the use of simple solar cookers in African refugee camps to broader regional alliances such as the recently launched Asia-Pacific Partnership on Clean Development and Climate. This voluntary partnership with Australia, China, Japan, India, and South Korea—countries that together with the United States represent over 50 percent of global energy use and greenhouse gas emissions—has as its goal the accelerated deployment of cleaner, more efficient technologies and the meeting of partners' respective national pollution reduction, energy security, and climate change objectives. The Asia-Pacific Partnership will engage stakeholders from key economic sectors as full partners in addressing clean development and climate issues in an integrated manner.

In order to foster public-private alliances, the U.S. Agency for International Development (USAID) created the Global Development Alliance in 2001. Through this innovative program, USAID has funded programs with nearly 400 alliances, with more than $1.4 billion in government funding leveraging more than $4.6 billion in partner resources.

The ultimate measure of the partnerships' success is whether they deliver concrete, on-the-ground results. When we talk about measurable results, a really positive story is emerging from some of the partnerships launched almost four years ago at the World Summit on Sustainable Development in Johannesburg. One example is the

Joerg Boethling/Peter Arnold Inc.

Women working below wind turbines in India.

Partnership for Clean Fuels and Vehicles, one of the four performance-based, market-oriented partnerships under President Bush's Clean Energy Initiative, a multifaceted approach to addressing access to energy and improving energy efficiency and environmental quality. In 2002, leaded gasoline was used in all but one country in sub-Saharan Africa. By the end of 2005, with the assistance of the Partnership for Clean Fuels and Vehicles, all 49 sub-Saharan African countries had stopped refining and importing leaded gasoline. This change will have a significant health impact on many of the 733 million people living in these countries.

The United States is committed to transparent reporting on the partnerships in which we participate. Toward that end, we have created a Web site—www.SDP.gov—to provide continuously updated information on U.S. sustainable development partnership efforts.

Building Effective Policy and Regulatory Frameworks

One of the keys to disseminating clean-energy technologies is ensuring the development of markets to receive them. Effective policy and regulatory frameworks at the local and national levels are absolutely necessary to encourage the level of private sector investment that will be needed in the coming decades.

The U.S. government is making significant progress to build capacity throughout the developing world. From our work on providing reliable energy services in poor slum areas in India to setting rules for power trading in Southern Africa to improved public participation in energy sector decision making globally, we are working with developing country ministries, utilities, and end-users to build the kind of institutional and market structures that will encourage investment in the energy sector.

The United States is also proud to work with its G8 colleagues and a number of other partners on the Extractive Industries Transparency Initiative (EITI). The EITI supports improved governance in resource-rich countries through the full publication and verification of company payments and government revenues from oil, gas, and mining.

Fostering Democratic Habits at the Grassroots Level

Increasing access to modern, clean, healthy, and efficient energy services can help lift people out of poverty

AP/Wide World Photo

Eurelios, an experimental solar power plant of the European Union, in Sicily.

and protect the environment. Perhaps equally important, the very act of providing energy services offers tremendous opportunities for communities to come together to learn and practice the fine art of democratic decision making.

The roots of strong democracies reach much deeper than the act of voting, resting on a foundation of social cohesion and participatory institutions. For the individual rural villager or urban slum dweller, the quest for energy services hinges on whether or not the institutions that serve the community are accountable to their constituency. Far too often, citizens' needs are not fully incorporated into political decisions about who gets what, when, where, and how.

A number of innovative electrification initiatives across the globe are addressing this problem by fostering local community structures that can bridge the gap between households and service providers. For example, USAID supported an alliance in Ahmedabad, India, in which local nongovernmental organizations served as intermediaries, assisting slum dwellers with financing and acquiring the appropriate documentation regarding land ownership to make them eligible for legal electricity service. The results are impressive. In the pilot project, 820 households were upgraded from illegal and unreliable service to regularized electricity. The utility is now rolling out the program to an additional 115,000 poor urban households. In Salvador, Brazil, the utility COELBA has hired local "community agents" to work with the local citizens and community leaders to identify and resolve problems, as well as to provide education on energy conservation practices. Thus far, COELBA has electrified more than 200,000 households. Building on this success, USAID and the

U.S. Energy Association are supporting a South-South exchange between COELBA and Angolan electric utility EDEL.

By involving community intermediaries in electrification efforts, these programs are strengthening democratic habits at the grassroots level. They build trust, form social capital, and allow people to voice their concerns. In so doing, they not only connect customers to electricity but also enable citizens to learn what it means to participate in democratic processes. This experience and these newly formed skills can easily be applied to other aspects of social and political life, ultimately contributing to a stronger, more robust, and more secure democratic culture.

Meeting the Challenge

The United States is pursuing a clean energy future that rises to the significant challenge before us. Our approach draws upon the best scientific research, harnesses the power of markets, fosters the creativity of entrepreneurs, and works with the developing world to meet our dual aspirations for vibrant economies and a clean environment. ■

PENNSYLVANIA
Changing the Way America Thinks About Energy

Kathleen A. McGinty

Pennsylvania is home to one of America's most progressive alternative energy portfolio standards, ensuring that 18 percent of all energy generated by 2020 comes from clean, efficient, and advanced resources. The clean energy law puts our state in the vanguard of a growing movement by state governments to ensure wide distribution and use of zero-pollution solar power, and it builds substantially on our leadership in wind production east of the Mississippi River. Pennsylvania Governor Edward G. Rendell personally led a campaign to attract the Spanish wind-energy company Gamesa Corporation, which is investing $84 million to locate its U.S. headquarters and four manufacturing facilities in Pennsylvania.

AP/Wide World Photo

Entrepreneur John Rich at a future plant in Gilberton, Pennsylvania, where waste coal will be converted into low-emission diesel fuel.

The state, traditionally known for its coal heritage, is using its purchasing power to stimulate the market for alternative energy projects by investing in advanced technologies that make these resources more competitive. Over the next decade, Pennsylvania will replace 3.4 billion liters of transportation fuel with locally produced alternative resources, such as ethanol and biodiesel, or with fuels derived from coal liquefaction. The 3.4 billion liters represents the forecasted amount of fuels to be imported from the Persian Gulf to Pennsylvania 10 years from now. The state will invest $30 million over the next five years to build refueling and production infrastructure to support wide distribution of the alternative fuels.

Pennsylvania very well could soon be the nation's leading producer of biodiesel, going from practically nowhere in early 2005 to a projected 151 million liters of annual production in the next 12 months. The state already is home to the East Coast's first state-of-the-art biofuels injection facility, which opened in late 2005 with $219,908 in state aid. The plant will help replace 12.1 million liters of imported oil with domestically produced biodiesel and keep at home $6 million by reducing the state's need to purchase fuels from other countries.

America's first coal gasification-liquefaction plant is being built in northeastern Pennsylvania. The facility will use waste coal to produce 151 million liters of clean-burning diesel fuel each year. What Pennsylvania is doing to support the project is unprecedented—creating a fuel consortium with private industry to purchase nearly all of the output. Pennsylvania will lock in its supply for some 10 years at prices well below current market values to ensure a long-term, viable market for the plant.

Pennsylvanians now spend some $30 billion per year on imported energy fuels. Instead of spending overseas, we are investing at home and putting Pennsylvanians to work. Brought back to life after years of inactivity, the Pennsylvania Energy Development Authority has awarded $15 million in grants and loans for 41 clean energy projects that will leverage $200 million in private investment. The projects will create 1,558 jobs in start-up construction and ongoing operations. The Pennsylvania Energy Harvest Grant Program has awarded $15.9 million and leveraged another $43.7 million in private funds since its inception in May 2003 for projects using sources such as wind, solar, biomass, waste coal, and recycled energy.

Advanced energy technology is about achieving both environmental protection and economic development. In Pennsylvania, we are changing the way America produces fuel and thinks about energy, attracting investments that stimulate the economy and create jobs, putting indigenous resources to work to enhance domestic security, and realizing significant improvements in environmental protection. ■

Kathleen A. McGinty is secretary of the Pennsylvania Department of Environmental Protection.

The opinions expressed in this article do not necessarily reflect the views or policies of the U.S. government.

REINVENTING THE WHEELS
The Automotive Efficiency Revolution

Amory B. Lovins

Ned Ahrens/King County Metro Transit

A new diesel hybrid-electric bus is tested in Seattle, Washington.

A "car-efficiency revolution" that could move the world beyond oil is in the making, as automakers start shifting to lighter-weight materials, sleeker aerodynamics, hybrid-electric propulsion, and non-petroleum fuels.

***Amory B. Lovins** is co-founder and chief executive officer of Rocky Mountain Institute, a nonprofit organization that fosters the efficient and restorative use of resources, and chairman of the composites-technology firm Fiberforge.*

Transportation drives global oil trade and is a key environmental challenge, especially in cities.

Most cities are designed around cars, not people—changing cars "from a convenient accessory of life into its central organizing principle," according to environmental author Alan Thein Durning. It need not be so. Moreover, new car technologies already exist, and others are under development, with potential to transform the paradigms of global development and energy security. These technologies, if pursued, will be good for business throughout the world, provide safe and affordable mobility, be environmentally friendly, and create competitive advantage. They are not the stuff of science fiction, but realities we can expect to see emerge even within this decade.

The world cannot go on turning nearly five trillion liters of oil per year, half of it for transport, into the roughly 42 percent of global carbon dioxide emissions reported by the International Energy Agency in its 2005 *World Energy Outlook*. Oil's direct and hidden costs—climate change, insecurity, geopolitical rivalry, price volatility, and degradation of economic and social development—make it unsupportable.

The most fundamental solutions are the simplest. More sensible land use strengthens neighborhoods and lets people be already where they want to be. Smart policies let all means of getting around—from walking and biking to ultralight trains and advanced buses—compete fairly at honest prices. From Singapore to Curitiba (Brazil), cities that treat cars without favoritism have no car problem, yet they achieve excellent mobility for all. In time, so could even the car-centric United States and other industrialized countries if they stopped incentivizing sprawl and cars through their tax systems and zoning laws.

Less driving is good. But with seven-eighths of the world's people without cars so far—China and Africa have only about the car ownership that America enjoyed around 1915—we will also need better cars. Fasten your seatbelt: Automaking's greatest revolution in a century is now gathering speed.

If the best conventional technologies now in some cars were in all cars, we would save at least a fourth of their fuel, repaying the investment in less than a year at current U.S. gasoline prices. But we can do better still by exploiting cars' physics.

New Automotive Materials

A modern car's engine, idling, driveline, and accessories dissipate seven-eighths of its fuel energy. Only one-eighth reaches the wheels. Of that, half heats the tires and road or heats the air that the car pushes aside. Only the last 6 percent accelerates the car (then heats the brakes when you stop). And since about 95 percent of the mass being accelerated is the car, not the driver, less than 1 percent of the fuel energy ultimately moves the driver—unimpressive, considering it is the fruit of 120 years of engineering effort.

Happily, three-fourths of a car's propulsive energy need is caused by its weight, and every unit of energy saved at the wheels saves another seven units we don't need to waste on the way to the wheels. Thus, making cars that are radically lighter weight has huge fuel-saving leverage.

Lighter weight formerly meant costly metals such as aluminum and magnesium. Now, ultralight steels can double a car's efficiency without extra cost or decreased safety. With clever design, even conventional steels can yield surprising results. A German startup firm's 2+2-seat 450- to 470-kilogram diesel roadster (www.loremo.com) combines 160- to 220-kilometer-per-hour (100- to 137-mile-per-hour) top speeds with a fuel economy from 1.5 to 2.7 liters per 100 kilometers (87 to 157 miles per U.S. gallon), and will sell in 2009 for 11,000 euros to 15,000 euros.

Advanced polymer composites are even stronger and lighter. They can halve a car's weight and fuel use, yet increase safety, because carbon-fiber composites can absorb up to 12 times as much crash energy per kilogram as steel. Such materials can make cars big (comfortable and protective) but not heavy (hostile and inefficient), saving both oil and lives. A new manufacturing process (see sidebar) can even make a carbon-fiber car cost the same to produce as its steel version. That's because its costlier materials are offset by simpler automaking and a smaller propulsion system.

For example, an uncompromised mid-size sport utility vehicle (SUV) designed in 2000 (figure 1), equipped with the most popular efficiency-doubling hybrid-electric drive system, could carry five adults in comfort and up to two cubic meters of cargo, haul a half-ton up a 44 percent grade, accelerate from 0 to 100 kilometers per hour in 7.2 seconds, be safer than a steel SUV even if it hits one, yet use less than a third the normal amount of gasoline, getting about 3.56 liters per hundred kilometers, or 67 miles per U.S. gallon.

Courtesy Hypercar Inc.

Figure 1: The Revolution concept car, an ultralight (857-kilogram) carbon-fiber mid-size sport utility vehicle, designed in 2000.

If produced at a rate of 50,000 cars per year, its retail price would be $2,510 (in year 2000 U.S. dollars) higher than today's equivalent steel SUV, but only because it is hybrid-electric, not because it is ultralight. Saved gasoline would repay this investment in two years at U.S. fuel prices or one year at European Union or Japanese fuel prices. Manufacturing such cars would use far less space and two-fifths less capital than today's leanest plant, thanks to up to 80-fold less tooling and to elimination of the body shop and paint shop—the two hardest and costliest steps in automobile manufacturing.

Alternative Automotive Fuels

Many cars already on the road can burn advanced biofuels—say, 15 percent gasoline and 85 percent ethanol, ideally cellulosic ethanol made with new processes from woody plants such as switchgrass or crop wastes. An ultralight hybrid car burning such "E85" fuel could cut its oil use by another three-fourths, to just 7 percent of the current level. Brazil has already eliminated its oil imports, two-fifths via sugar-cane ethanol that now competes without subsidy. Three-fourths of Brazil's new cars can burn anything from pure ethanol to pure gasoline, although all of its gasoline is at least 20 percent ethanol. Sweden plans to be oil-independent by 2020, chiefly via ethanol made from forest wastes and the requirement that its top-selling 60 percent of filling stations offer renewable fuel by 2009.

In the longer run, one can make a robust business case for tripled-efficiency, ultralight-hybrid cars to use compressed hydrogen gas as fuel and turn it into electricity in a fuel cell. A heavy, inefficient car would need an excessively bulky tank and a big, costly fuel cell. But an ultralight, aerodynamic car would need two-thirds less propulsive energy and smaller tanks. And just 3 percent as much cumulative production volume would be needed to make the three-fold smaller fuel cell cost effective—thus it could become cost effective many, many years earlier. Such cars when parked (which is 96 percent of the time) could even become profitable power plants on wheels, selling electricity back to the grid when and where it's most valuable. In a parking structure, there would be a pipe to get hydrogen into the car and wires to get electricity out. At times of peak power demand, you could turn the fuel cell on and the car could run as a power plant, crediting the owner's account.

Meanwhile, adding more batteries to conventional hybrid cars, if cost effective, could displace fuel now used for short and, perhaps, medium trips.

Cost-Effective Technologies

The modern car needs to be functional, aesthetic, safe, fuel-frugal, and affordable. Makers of cars and public policy often assume that efficient cars must be small, sluggish, unsafe, ugly, or costly. But integrative design and new technologies can achieve all desired car attributes, today and tomorrow, simultaneously and without compromise. We therefore will not need high fuel taxes or efficiency standards to induce people to buy unattractive cars; rather, they'll want to buy the super-efficient cars because they're *better*, just as most people prefer digital media to vinyl records.

AP/Wide World Photo

An electric car is recharged at an alternative fuel station in San Diego, California.

For conventionally improved cars that do cost more up front, car buyers' short view—looking at just the first two to three years' worth of fuel savings—is a big obstacle. High fuel prices discourage driving but have little effect on car choices because they're diluted by nonfuel costs, then heavily discounted. The most powerful way to influence car choice is "feebates." Within each size class, new-car owners pay a fee or get a rebate—which and how big depend on a car's efficiency—and the fees pay for the rebates. The increased price spread encourages a buyer to buy an efficient model of the size he or she prefers. The buyer saves money; automakers make more profit; national security improves. Such feebates, now starting to emerge around the world (in Canada, France, and some states in the United States), are more effective and politically attractive than fuel taxes or standards.

The car-efficiency revolution faces many challenges, but each can be overcome. Hybrids, invented by Dr. Ferdinand Porsche in 1900, were reengineered nearly a century later by Japanese automakers with strong leadership and balance sheets. These popular hybrids now offer up to doubled efficiency, many with boosted performance as a free bonus.

U.S. automakers are playing catch-up and need help with retooling and retraining (which needn't cost the Treasury). Their choice is stark: whether America will continue to import efficient cars to displace oil, or *make* efficient cars and import neither oil nor cars. A million jobs hang in the balance. But the process Austrian economist Joseph Schumpeter called "creative destruction" is sweeping the overbuilt auto business: The market will change either the managers' minds or the managers, whichever comes first.

China's and India's ambitious automakers will quicken the pace, leapfrogging over Western technology. And countries without an auto industry may choose to start one of a wholly new kind—not based on steel, but more like making computers with wheels than cars with chips.

Altogether, tripled-efficiency cars, trucks, and planes are feasible with today's technology, repaying their extra cost in a year or two. More efficient use of oil in buildings and industry, and substituting saved natural gas and advanced biofuels, could together *eliminate* U.S. oil use by the 2040s, revitalize the economy, and stop 26 percent of carbon dioxide emissions. Getting off oil altogether would cost an average of $15 per barrel (in year 2000 U.S. dollars)—a fifth of the recent world oil price—so the transition will be led by business for profit.

A U.S. version of such a transition was mapped by my team's 2004 Pentagon-cosponsored study *Winning the Oil Endgame*, and implementation is under way—for example, Wal-Mart doubles its heavy trucks' efficiency, Boeing markets the 20 percent-more-efficient (at no extra cost) 787, and the Pentagon explores radically more efficient military platforms whose technology could transform civilian vehicles much as military research and development created the Internet. Other countries can do as well or better if they just aim high, think boldly, and take markets and technological progress seriously. Super-efficient cars, and their analogues in other kinds of vehicles, are among the best ways to make the world richer, fairer, and safer. ■

The opinions expressed in this article do not necessarily reflect the views or policies of the U.S. government.

PROGRESS IN MAKING AFFORDABLE LIGHT AUTO MATERIALS

Amory B. Lovins

Carbon fiber—stiffer and stronger than steel but a third its density—embedded in plastic resin forms very light and strong "advanced composite" material, analogous to wood (cellulose fibers embedded in lignin) or concrete (steel rebar embedded in cement and aggregate). Advanced composites, increasingly familiar in sporting goods, have long been used in military and aerospace structures, but to compete in automaking their production must become about a thousandfold cheaper and faster. The handicraft process for placing the carbon fibers in the proper positions, impregnating them with liquid resin, and slowly baking the combination to "cure" it by a chemical reaction is far too slow and costly for making auto bodies: Specialty cars made in this way, like the Formula One-inspired Mercedes SLR McLaren, cost hundreds of thousands of dollars.

Courtesy DaimlerChrysler

Carbon-fiber composites are used to make doors, hood, and body for the Mercedes-Benz SLR McLaren at a plant in England.

Some automakers are making encouraging progress in bridging this cost gap. BMW has 60 specialists perfecting its proprietary process, which uses the world's biggest resin-transfer-molding press and is already making more than a thousand carbon-fiber roofs and hoods per year for high-end models. Toyota and Honda are widely believed to want to migrate advanced manufacturing technique from their carbon-fiber airplane divisions back to automaking.

Meanwhile, higher-volume production, especially for aerospace (over half the weight of Boeing's new 787 is advanced composites), is making composite materials better and cheaper, and innovators outside the auto industry are developing new manufacturing processes.

For example, a small private Colorado firm, Fiberforge, a firm this writer chairs and owns stock in, is working with automakers, their suppliers, and other industries to commercialize a novel process that appears able at scale to achieve 80 to 100 percent of the performance of hand-layup aerospace composites at 10 to 20 percent of their cost. This process first makes a flat "tailored blank"—super-strong polymer "plywood" with variously oriented layers of carbon fiber and thermoplastic—automatically and precisely formed by a digitally controlled machine akin to an inkjet printer. The tailored blank is then heated until the thermoplastic softens, and stamped on a hot die in a conventional thermoforming press to mold it into the desired complex shape. One minute later, the cooled part is ready to trim and use.

Further information is available at http://www.fiberforge.com/ and in the trade press articles and technical papers linked to that site. ■

Amory B. Lovins is co-founder and chief executive officer of Rocky Mountain Institute.

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THE RENAISSANCE OF NUCLEAR ENERGY

James A. Lake


Constellation Energy

The Calvert Cliffs nuclear plant in Maryland seen from the Chesapeake Bay.

Nuclear power renewal promises to energize electricity generation worldwide and help address concerns about greenhouse gas emissions, despite remaining challenges. In the long term, nuclear energy could become safer and more economical, proliferation resistant, and sustainable.

James A. Lake *is associate laboratory director for the nuclear program at the Idaho National Laboratory and was president of the American Nuclear Society in 2000-2001.*

The strong economic and safety performance of nuclear power in the United States, the growing demand for energy, and the increasing awareness of the environmental benefits of clean nuclear power form the foundation for a nuclear energy renaissance that can support U.S. energy security, economic prosperity, and environmental quality goals in the 21st century. However, before such a renaissance can become a reality, policy makers must respond to major challenges in such areas as the relatively high capital costs of new plants, sustainable management of used nuclear fuel, and the risks of proliferation of weapons-grade plutonium from the nuclear power fuel cycle.

NUCLEAR POWER DEVELOPMENT IN THE UNITED STATES

Nuclear power in the United States was born in the 1950s and 1960s to unreasonable and, as it turned out, unachievable expectations of being so inexpensive that it was "too cheap to meter." As the first nuclear power plants were built and operated, they began to experience difficulties with rising construction costs and with safety performance, culminating in the accident at the Three Mile Island Unit II plant near Middletown, Pennsylvania, in 1979. The subsequent corrective actions put in place by the U.S. Nuclear Regulatory Commission (NRC) to assure safe operations delayed for many years completion of plants under construction during a time of double-digit inflation and caused several of these plants to go bankrupt and be cancelled, thus ending the first era of U.S. nuclear power.

Throughout the 1980s, the nuclear electric utilities completed many of the remaining plants, brought them on line, and devoted their attention to improving cost effectiveness and operations performance, which simultaneously improved safety. By the mid-to-late 1990s, the 103 nuclear power plants in the United States were producing 20 percent of America's electricity at a cost that made them highly competitive with those fired by coal and other fuels—less than 2 cents per kilowatt-hour. Furthermore, their safety performance has improved by more than a factor of 10, to a point where nuclear power is a leader in industrial safety performance today. By the end of the 1990s, with rising energy prices and major blackouts in California, U.S. business interest in nuclear power turned up. Several large utilities, such as Exelon and Entergy, bought nuclear power assets from smaller, less profitable utilities as the business environment for nuclear power began to improve.

Today, more than half of currently operating U.S. nuclear power plants have sought and received 20-year extensions to their original 40-year licenses. The industry fully expects all U.S. plants to apply for these extensions as their original license periods expire. Such extensions would ensure that these large capital assets continue to produce electricity while Americans continue to enjoy their financial and environmental benefits.

As we close out the second era of nuclear power, the era of financial and safety recovery, nuclear power is poised to contribute even more to U.S. and world energy needs. This recovery will be fueled in part by growing national energy security concerns and the rising costs of imported fossil fuels; substantial demand growth for energy to fuel our economic prosperity; increased attention to eliminating environmental threats associated with burning fossil fuels and substituting emissions-free nuclear power; and an electricity market very favorable to inexpensive nuclear power.

Public trust in the operation of nuclear power plants has steadily improved with better understanding of the economic and environmental benefits and with improved safety performance. Some polls show that 70 percent of Americans favor continued operation of the existing plants, and more than 50 percent support building new plants.

Today, 440 nuclear power plants generate 16 percent of the world's electricity needs. Aggressive new nuclear plant construction programs have begun, particularly in East Asian countries, Russia, and India. The United States itself is on the verge of resuming construction of new nuclear power plants, a process that has been dormant for more than 25 years. This is the beginning of the third era, the renaissance of nuclear energy.

To fulfill robust expectations, nuclear power needs to meet four principal challenges:

- First, nuclear power must remain economically competitive in the world energy market; in particular, energy companies must better control capital costs.
- Second, in order to satisfy the public's expectations of exceptional safety performance, current plants must continue to operate safely and future plants must continuously improve safety in expanding world markets.
- Third, nuclear power and its fuel cycle must be viewed by the public and by national leaders as sustainable; in particular, used nuclear fuel must be managed in a manner that is cost effective and safe for the extended period of time that used fuel remains highly radioactive, and the nuclear fuel supply must be extended for centuries in the face of depleting fossil fuels.
- Fourth, the nuclear materials from the fuel cycle must be protected from proliferation and misuse for non-peaceful purposes.

"We stand at the verge of a renaissance of nuclear energy, founded in the continued safe and economical operation of America's 103 nuclear power plants and signaled by the expected near-term announcements of several orders for new nuclear power plants to be constructed and operated in the next 10 years."

AP/Wide World Photo

Tests are run on the advanced test nuclear reactor at Idaho National Laboratory.

On August 8, 2005, President George W. Bush signed into law the Energy Policy Act of 2005, which authorizes long-term budgets for these programs, including loan guarantees, production tax credits, and protection for private sector investment in the construction of the first few new nuclear power plants. (These plants face risks associated with the new licensing process and with reestablishment of the U.S. design and construction infrastructure.) The act further provides funding authorization for long-term nuclear energy research and development programs, including the Generation IV advanced reactor development program and the Advanced Fuel Cycle Initiative, which together have grown into the Global Nuclear Energy Partnership (GNEP).

Nuclear Power 2010: The focus of the Nuclear Power 2010 program is on testing and validating a new NRC licensing process based on certification of the safety of the reactor system design, issuing a permint for the proposed reactor site, and issuing a combined license for construction and operation of a certified reactor design on a permitted power plant site.

Four advanced reactor designs developed by Westinghouse and General Electric have already received NRC certification, and another six are still in review, with at least two of these expected to be certified by 2008 to 2010. Early site permit applications were submitted by three groups for at least six potential new plant sites and are under review. Finally, 12 utilities have notified the NRC of their plans to seek construction and operating licenses for as many as 23 new reactors. It is expected that the first formal nuclear power plant orders will be placed by late 2007 or early 2008.

Generation IV and the next-generation nuclear plant: The Generation IV advanced reactor roadmap was developed by more than 100 international nuclear experts to evaluate and prioritize six next-generation reactor technologies that have strong potential to be more economical, safer, more sustainable, and more proliferation resistant than existing technologies. The very-high-temperature gas-cooled reactor and the sodium-cooled fast reactor have emerged as the priority technologies for international development and demonstration.

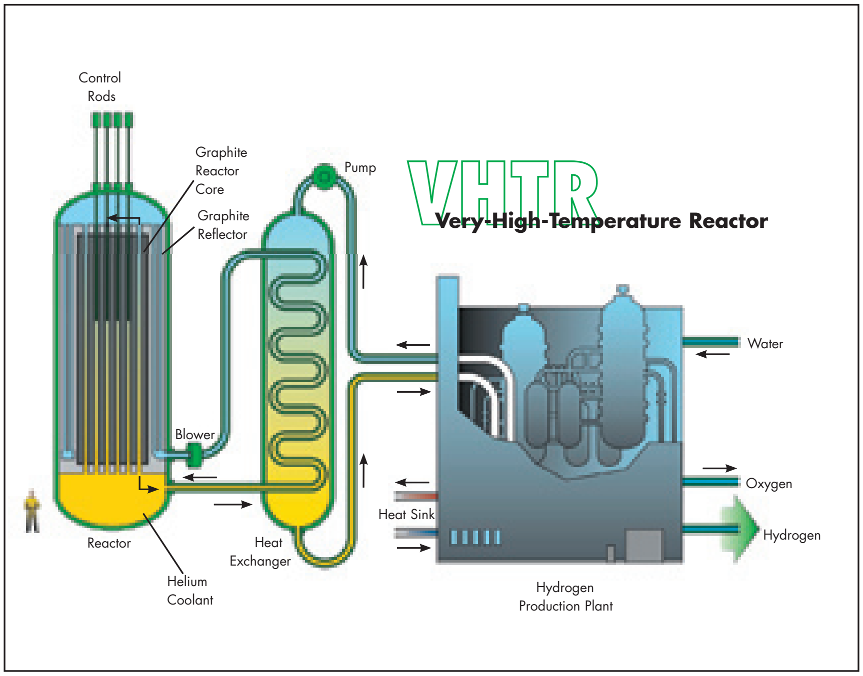
The next-generation nuclear plant is based on a gas-cooled technology that can operate at temperatures of 850 to 950 degrees Celsius with greatly improved thermal efficiency for electricity production, but notably in a tem-

A New Direction for U.S. Nuclear Power

In 2001, the U.S. government issued a new National Energy Policy (NEP) that set the nation on a course to expand the use of nuclear energy in the near term by making more efficient the processes of obtaining extensions of licenses to operate existing nuclear plants and of obtaining licenses to build new nuclear facilities. The NEP further sought to encourage nuclear energy use through the development, demonstration, and deployment of next-generation nuclear power technologies. Importantly, it aimed at achieving this goal through research and development of advanced fuel cycles that might prove to be cleaner, more efficient, less waste intensive, and more proliferation resistant than a single-use nuclear fuel, which requires geologic disposal of the used fuel.

Several programs were put in place to implement the NEP, including:

- the Nuclear Power 2010 program to encourage the near-term construction of new nuclear power plants;
- the Generation IV program to develop next-generation reactors that are more economical, safer, more sustainable, and more resistant to proliferation of weapons-grade plutonium;
- the Advanced Fuel Cycle Initiative to investigate advanced reprocessing and recycle strategies for used nuclear fuel that extract substantially more energy from uranium resources by burning up long-lived constituents in used nuclear fuel in a manner that does not separate plutonium. Such technologies promise to reduce the amount of used fuel, potentially extending the life of the planned Yucca Mountain geologic repository for spent nuclear fuel and radioactive waste.



Courtesy of Idaho National Laboratory

Diagram of a very-high-temperature reactor.

perature range that may enable high-efficiency production of hydrogen. High-efficiency, emissions-free production of hydrogen is a critical element of President Bush's efforts to displace increasingly expensive imported oil with hydrogen as a domestic transportation fuel—initially to enrich heavy domestic crude oil, but subsequently to produce synthetic transportation fuels, and, ultimately, to power fuel cell vehicles. It is important, therefore, that the next-generation nuclear plant can not only generate electricity but also produce hydrogen for the transportation sector and heat for industrial processes, the areas in which the heavy U.S. dependence on imported oil is a threat to our economic prosperity.

The Advanced Fuel Cycle Initiative and the GNEP: The GNEP was announced by President Bush in early 2006. It is intended to substantially accelerate the U.S. advanced-fuel-cycle and fast-reactor technology development efforts. The goals of the program are these:

- to reduce the burden related to geologic disposal of used nuclear fuel in terms of waste volume, heat load (as the radioactive fuel decays, it gives off huge amounts of thermal energy), radiotoxicity (levels of radiation that become toxic to living cells or tissue), and number of repositories that will be needed in the 21st century;
- to recover the substantial energy value contained in used nuclear fuel;
- to increase the proliferation resistance of used nuclear fuel recycle processes.

In order to meet these goals, three technologies will be developed and demonstrated. They are (1) the transmutation of the materials in used nuclear fuel in a new generation of sodium-cooled fast-spectrum advanced burner reactors to extract their energy value and to render the ultimate nuclear wastes more manageable with a single repository; (2) the separation of the elements of used nuclear fuel coming from the fleet of water-cooled reactors into uranium, reusable fuel components, and fission product wastes using a uranium extraction process called UREX+ that does not separate weapons-usable plutonium; and (3) the development and demonstration of fuel-recycle and fuel-fabrication technologies for the advanced burner reactors.

Outlook

We stand at the verge of a renaissance of nuclear energy, founded in the continued safe and economical operation of America's 103 nuclear power plants and signaled by the expected near-term announcements of several orders for new nuclear power plants to be constructed and operated in the next 10 years. In the longer term, our national laboratories are working with the nation's universities, U.S. industry, and the international community to develop the next generation of advanced nuclear power systems, which will be even more economical, safer, and sustainable with a closed fuel cycle that burns up substantially more of the nuclear fuel to extract much more of its energy potential while minimizing the quantities of nuclear waste. Nuclear power has an important place in America's energy future, safely providing electricity and transportation fuel products that are economical, clean, and sustainable. ■

The opinions expressed in this article do not necessarily reflect the views or policies of the U.S. government.

CONDITIONS SHIFT IN FAVOR OF NUCLEAR POWER

Andrew Paterson

The dramatic recovery of interest in nuclear energy is likely to lead, in 10 years or so, to construction of the first nuclear power units in the United States in 25 years. Expectations for the economic viability of new nuclear power projects are rising due to several factors.

Competitive production costs and reliability: In the United States, nuclear power production costs at existing plants are a bit below those of coal-fired plants and roughly one-third of gas-fired plants, according to the Utility Data Institute private directories and data bases. However, this is because the capital equipment costs for the 103 U.S. reactors are now fully recovered by their owners. Uranium fuel prices—below half a cent a kilowatt-hour (kWh)—though rising recently, have been more stable and much lower than gas prices. Moreover, uranium fuel comes from stable allies Canada and Australia, not volatile supply sources in the Middle East. And recycling Russian warhead material from the Cold War actually provides half our fuel. Lastly, nuclear plants run continuously, regardless of weather, making them the most reliable source of large-scale electricity.

Potential for lowering construction costs: Nuclear power plants have the highest construction costs in the large-scale power generation sector. In recent years, however, an international market for nuclear reactors has emerged. U.S. plant owners are developing alliances to provide a string of orders on standardized designs certified by the U.S. Nuclear Regulatory Commission (NRC) that should bring down single-unit prices. By teaming up, utilities provide reactor vendors and engineering firms with a 20-year sales curve, allowing them to efficiently staff up and order large components. With multiple orders, the capital costs of new units can be brought down to around $1,200 to $1,500 per kilowatt-electric (kWe) from roughly $2,000 to $2,300 per kWe for first units. By comparison, capital costs for coal-fired plants are around $1,300 to $1,500 per kWe (depending on whether they combust or gasify the coal), and those of gas-fired plants are around $600 per kWe.

Predictable licensing: The NRC has redefined the licensing process for nuclear power plants—perceived by the industry as a "showstopper"—making it more predictable without compromising on safety. The NRC reforms will be tested in the near future with government help, under the Energy Department's Nuclear Power 2010 program. Unlike the "greenfield" plants of the 1970s, however, the first new reactors will be added to current nuclear sites where infrastructure is already in place and communities support them, primarily in the Southeast.

Advanced plant design and experience: Instead of varying designs, the NRC is now certifying only a few reactor designs. And, more important, plant design and production are now much more advanced than they were 25 to 30 years ago, when the last U.S. reactors were ordered—before automated computer-aided design/computer-aided manufacturing (CAD/CAM) was available. Thousands more hours of experience worldwide since 1980 have strengthened the design and engineering process.

Government financing: Government support for the first few new reactors—in the form of loan guarantees, production tax credits, and federal risk insurance for commissioning delays—monetizes the emissions savings of nuclear power and will help the industry address regulatory uncertainties beyond their control. Interest rates are also significantly lower than in the late 1970s (a prime rate at 5 to 6 percent now versus 15 percent then). More reactors were cancelled because of high interest rates than as a result of the accident at Three Mile Island in March 1979.

Nuclear vs. natural gas: In the 1990s, after passage of the Clean Air Act, relatively cheap natural gas emerged as the most popular clean alternative. The capital costs of nuclear power—which can be three times higher than those of gas plants—and other factors, such as the four- to six-year construction cycle, made nuclear power unattractive to investors and utilities. But gas prices have risen dramatically since then and remain volatile. A 2001 study by the Electric Power Research Institute projected that new nuclear capacity could be economically viable if natural gas prices stayed above $5 per million British thermal units (BTU). In fact, prices are trading between $8 and $12 per million BTU for December 2006 delivery. ■

Andrew Paterson is a partner with Environmental Business International, a firm specializing in market data and strategic intelligence for energy and environmental industries (www.ebiusa.com). He also serves as a consultant for Technology Management Services, a firm specializing in technical support to federal agencies, principally the Department of Energy.

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RENEWABLES
Looking Toward Inexhaustible Energy

Michael Eckhart

Courtesy Wade Newhouse/ Stirling Energy Systems, Inc.

An artist's rendering of a planned Stirling Energy Systems solar power plant in the Mojave Desert, California.

A major expansion of renewable energy worldwide will require innovative government policies, a stable and predictable investment environment, and technology transfers to the developing countries.

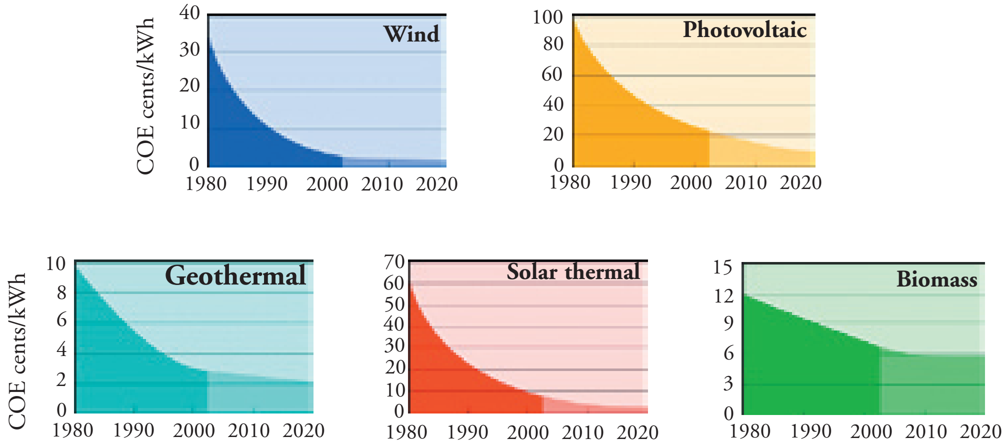
Michael Eckhart *is president of the American Council on Renewable Energy (ACORE), a nonprofit organization based in Washington, D.C. ACORE staff members Peter Gage and Cameron McCarter contributed to this article.*

The renewable energy sector is about to turn a corner. Commercially available and economically competitive in many locations, renewables will further U.S. national interests by helping end our addiction to oil and begin to address the issue of global warming. The industry is poised for Phase II, putting America's 30-year, $15 billion investment in research, development, and demonstration of renewable energy technologies to use in the marketplace.

Market Drivers

There are three key drivers pulling markets toward renewables. The first is national energy security. Current projections show U.S. oil consumption increasing and outpacing flat domestic production curves, leaving the United States increasingly dependent on foreign oil

Decline in Renewable Energy Costs



These graphs are reflections of historical cost trends, NOT precise annual historical data.
COE = Cost of Energy.
Source: National Renewable Energy Laboratory (www.nrel.gov/analysis/docs/cost_curves_2002.ppt).

markets. This would make the U.S. economy vulnerable to disruption in oil imports.

Additionally, the rapid growth of developing countries such as China and India places an increasing strain on world oil markets, a problem that is likely to get worse over time. The effects of this can already be seen: The price of oil surpassed $70 per barrel in mid-June 2006, up from $30 only a few years ago. Renewable energy can help the United States rely on domestic sources of energy, which will reduce our need for oil or lessen the growth of our consumption.

A second driver toward renewable energy is concern about climate change. Renewable energy can help provide for our energy requirements while decreasing our greenhouse gas emissions. According to several news sources, more than 2,000 scientists have concurred that greenhouse gases such as carbon dioxide and methane are building up in the Earth's thin atmosphere and that this buildup of gases is increasing global temperatures. Many of these scientists believe that this increase of temperatures portends negative and potentially catastrophic consequences, that the time frame for addressing the issue is now, and that there are actions that can be taken. Use of carbon-free renewable energy is one of them.

A third market driver is the cost of renewable energy, which has been decreasing for decades and is projected to continue to decrease for some renewables, as shown in the figure above. The decreasing costs of renewable energies can be attributed to improvements in the technologies of the renewables. As the industry matures, costs will continue to decrease.

Putting Renewable Energy to Use

The uneven distribution of renewable energy resources across the United States makes it difficult to have a single, sweeping national policy. Solar energy is strongest in the Southwest; wind power is most used in the Great Plains, on mountain ridges, and offshore; and geothermal energy is available in the West. Biomass is available across the country, but regionally in different forms. Biofuels are being produced in the farming states but consumed in cities that have air quality restrictions.

There are multitude of local markets for renewable energy across America, each with unique resources, economics, culture, and politics. Individual states have taken the lead in the renewable sector. Nearly half of the states employ a renewable portfolio standard (RPS)—a system of goals for producing renewable energy. The employment of RPSs at the state level requires utilities to provide a particular amount of energy from renewable sources by a specific date, thus creating new demand for renewable energy immediately.

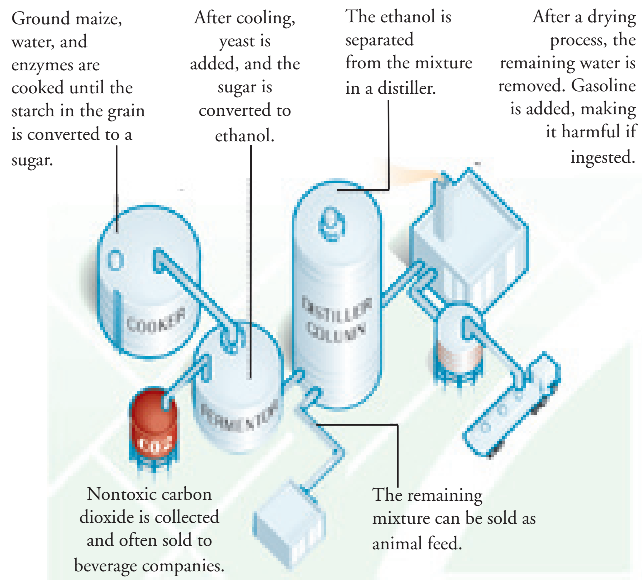
Elsewhere, the European Union has taken steps toward promoting renewable energy use and is a source of policy innovation. Germany, Spain, Italy, and others have implemented feed-in tariffs—the price per unit of electricity that a utility or supplier has to pay for renewable electricity from private generators. Meanwhile, Finland, Greece, and the United Kingdom have grants, tax incentives, and mandates for people to produce or use green power.

There have been widespread efforts to deploy renewable energy in the developing countries, with funding by the U.S. Agency for International Development and many donor agencies, and with financing support by the World Bank, European and other regional development banks, and the private sector. India was one of the first to commit to broad-based use of renewables and is active in wind, solar, hydro, and biomass energy. Brazil has been the early leader in sugar-based ethanol. Southern India, Sri Lanka, and Bangladesh have developed markets for the use of solar photovoltaics (PV), getting initial electricity to off-grid homes. China has developed a $3-billion-per-year solar water heating industry.

Maize-Based Ethanol Into Gasoline

The United States produced about 3.4 billion gallons of fuel ethanol in 2004. Almost 86 percent of that came from the Midwest, which produces more than two-thirds of the nation's maize.

Making of fuel ethanol



AP/Associated Press Graphics

Wind Power

Wind power is the leader in *wholesale* renewable electricity production in the United States. Total installed U.S. wind power capacity was 9,149 megawatts at the beginning of 2006, according to the American Wind Energy Association. A large part of this—2,420 megawatts—was installed in 2005, and an estimated 3,000 megawatts is planned for installation in 2006. With recent technological advances, the price competitiveness of wind generation versus natural gas has improved, supporting continued growth. In addition, the U.S. federal government offers companies a production tax credit for wind power equal to about 1.9 cents per watt-hour. This has been a powerful incentive to attract tax-oriented investors, such as utility companies, into wind farm ownership.

The original market for wind power was Denmark in the late 1990s, followed by Germany. Today, the hot markets are Spain, Italy, France, the United Kingdom, and India. But wind power is available almost everywhere.

Solar Energy

Solar PV, a $12-billion global industry, is the leading renewable power source for *distributed* power generation (consumers who generate heat or electricity for their own needs and send surplus electrical power back to utilities), with recent growth in Japan, Germany, and Spain.

In 2005, the U.S. Energy Policy Act established a 30 percent federal tax credit for solar systems purchased for both residential and business applications in the United States, on top of substantial subsidy programs in states such as California and New Jersey.

In the developing countries, PV has great opportunity but has proven difficult to implement because it requires a local infrastructure of companies to sell, install, and service the equipment, and needs financing, which often is not available. Yet, markets are growing in India, Sri Lanka, Bangladesh, Morocco, Kenya, South Africa, and elsewhere.

Biofuels

Biofuels, principally maize-based ethanol, present the biggest investment opportunity in renewable energy in the United States for the next several years. Recent evidence assembled by Lawrence Berkeley Laboratory rebuts outdated beliefs from the 1970s that, because of the energy-intensive production, environmental benefits from maize-based ethanol are nonexistent. It now appears that producing maize-based ethanol requires much less petroleum than producing gasoline and that greenhouse gas emissions from such an ethanol are about 15 percent to 20 percent lower than from gasoline. New cellulosic ethanol technology reduces both greenhouse gas emissions and petroleum inputs even more substantially. With ethanol replacing methyl tertiary-butyl ether (a chemical compound used as a fuel component in gasoline that has been banned in 22 states), demand has grown rapidly. In 2006, more than 4.7 billion gallons (17.9 billion liters) of ethanol will be produced, and there are 2 billion gallons (7.6 billion liters) per year of new processing capacity under construction in the United States.

The U.S. auto manufacturers have taken notice of the recent interest in biofuels. General Motors, for example, currently produces nine models that can run on E85, a mixture of 85 percent ethanol and 15 percent gasoline.

Investment

Large investments are being made in renewable energy companies and projects. Venture capitalists invested close to $181 million in alternative energy companies in 2005, an increase of $78 million from the previous year, according to PricewaterhouseCoopers, Thomson Venture Economics, and the National Venture Capital Association.

Major industry leaders have begun to take notice of this growing market opportunity and are showing their support. For example, General Electric recently invested $51 million in a 50-megawatt wind project in California, and Cascade Investment LLC placed $84 million into Pacific Ethanol, which produces and markets renewable fuels. The accelerated market growth has created a favorable environment for investors, with opportunities for substantial profits, as well as risks, in this now $50-billion-a-year industry.

Simon Fraser/Photo Researchers Inc.

Geothermally heated greenhouse in Hveragerdi, Iceland.

National and Global Benefits

Renewable energy is a broad category of sources that draws from the naturally available energy around us. While not a silver bullet, the more we use it, the better off we will be in terms of reducing oil imports, reducing pollution and greenhouse gas emissions, and increasing jobs.

Renewable energy can provide significant opportunities for developing countries and rural areas. For example, by providing new jobs and new sources of income for farmers and ranchers, the Colorado Green Wind Farm in Lamar, Colorado, boosted the local county tax base by 29 percent, increased the school general fund by $917,000 per year, and increased funding of the county medical center by $189,000.

The potential of renewable energy is vast. It contributes to America's needs for security of supply, a cleaner environment, good jobs, and investment opportunities. The rural sector of America stands to receive the most benefits from renewable energy development.

Such development also offers opportunity to the rural people of the world everywhere to gain access to modern forms of energy. Wind, solar, geothermal, biomass, and small hydro plants can generate electricity for rural utilities and villages. Solar PV and solar water heating can bring modern energy to homes.

Outlook

The outlook for renewable energy in the United States and around the world is positive and accelerating. This is a challenge for government policy planners who have to rely on computer modeling projections that can be out of date because oil prices have increased rapidly and demand for renewable energy has accelerated. For example, while the official U.S. forecast from the Energy Information Agency shows renewable energy contributing only about 10 percent of U.S. energy supply in 2030, various industry groups are more optimistic. The Energy Future Coalition is calling for 25 percent by 2025, and ACORE sees the potential for 20 percent, 30 percent, and 40 percent by 2020, 2030, and 2040, respectively.

To make this happen, conventional energy prices must continue to stay high, renewable energy costs must continue to come down, and government policies must be stable and predictable to encourage commitment of lenders and investors to the financing of renewable energy systems. There also must be international collaboration to transfer the technologies to the developing countries. ■

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AMORE
Renewable Energy for Development in Mindanao

A solar panel is not just a solar panel—a device generating "clean" electricity. In the developing world, it can open the door to development and light the road to it, too.

In the Philippine's Autonomous Region in Muslim Mindanao, ravaged by three decades of civil unrest, solar photovoltaic panels and micro-hydropower systems have helped improve public health and education, nourish entrepreneurship, empower women, and enhance a sense of community and peaceful coexistence. The panels were installed by the U.S. Agency for International Development's (USAID) Alliance for Mindanao Off-Grid Renewable Energy (AMORE). AMORE was established in 2002 to provide electricity from renewable sources to villages on the southern Philippines islands, which are far from the national energy grid.


Alliance for Mindanao Off-Grid Renewable Energy.

Villagers erect a solar photovoltaic panel in Mindanao, Philippines.

As of March 2006, AMORE had electrified more than 1,300 households, community centers, and streets in 227 *barangays* (villages). In the future it plans to equip with sustainable, renewable small-scale energy systems at least 170 more remote rural communities in the region.

Solar-powered lights cost 70 percent less per month to operate than kerosene lamps and save the carbon dioxide such lamps produce from entering the atmosphere. AMORE's efforts are helping to increase outdoor safety and significantly boost business and educational productivity by allowing work and study to extend into evening hours. Maintained by community development groups, the stand-alone energy systems also enable aspiring entrepreneurs to pursue new small-business projects such as mat-making and other local crafts.

But the development drive does not stop there. Electrification has given an impulse to related programs—installing solar-driven pumps to provide clean drinking water and irrigate vegetable farms, as well as delivering audio materials through radio to villagers wanting to study English. AMORE also has promoted using renewable energy for fish drying, for producing fish and seaweed by aquaculture, and for powering public telecommunications offices, a community computer center, and cable TV facilities. Some of these projects attracted partners that were not part of the original alliance.

AMORE energized the village of Chua in Bagumbayan, Sultan Kudarat, when it installed an 8-kilowatt micro-hydropower system and established a spring-fed potable water system, an integrated grain and bean mill, and a vegetable farm. Electrifying the local school enabled powering distant educational facilities.

In the village of Kahikukuk in Banguingi on the island province of Sulu, a potable water system is expected to reduce the incidence of diarrhea and other waterborne diseases. Before the system was installed, the village residents—mostly women and young girls—fetched water from unsafe makeshift wells 1.5 kilometers away from their residences.

AMORE applies in practice the idea of self-propelled development. Putting the operation and maintenance of energy and other systems into the hands of local development groups has ignited a sense of community and responsibility. Such a group in Barangay Lagasan not only used its own resources and funds to protect the systems from pilferage, but also raised funds to purchase a streetlamp. The U.S. embassy in Manila concluded in an article published on its Web site that Barangay Lagasan and similar groups have evolved into organizations that promote community progress. An island community leader was heard saying: "Among the best things that the AMORE program has done in our community was that they provided the light that brought us closer."

The AMORE Alliance includes the Autonomous Region in Muslim Mindanao, the government of the Netherlands, Mirant Philippines Corporation, the Philippines Department of Energy, Shell Solar, and SunPower Corporation. ■

CONVENTIONAL BIODIESEL CROPS

Typical crops for conventional biodiesel production include soy, sunflower, rapeseed, palm, and other oilseed bearing crops such as jatropha.

Soybeans are grown as a commercial crop in more than 35 countries. The major producers are the United States, China, the Democratic People's Republic of Korea, the Republic of Korea, Argentina, and Brazil. Soybean is grown primarily for the production of seed. It has a multitude of uses in the food and industrial sectors (including biodiesel production) and represents one of the major sources of edible vegetable oil and proteins for livestock feed use. Soybeans are often rotated with such crops as maize, winter wheat, spring cereals, and dry beans.

The many diverse species of sunflowers produce two types of seeds: oil-bearing and edible. Oil seeds have an oil content greater than 40 percent and are best suited for biodiesel production. The main producers of sunflower seeds are Russia, Ukraine, and Argentina, but sunflowers are also widely cultivated in China, India, the United States, and Europe. Yields vary widely according to the growing environment. Water availability is the main cause of the variations.

Rapeseed (colza) is a member of the mustard family. Two types of rape are commonly cultivated to produce either tuber-bearing or oil-bearing rapeseed. Rapeseed is used for the production of edible oil in Asia and elsewhere for the production of animal feed, vegetable oil, and biodiesel. China, India, Europe, and Canada are now the top producers, although rapeseed can be successfully grown in the United States, South America, and Australia. The spring-type oleiferous rapeseed performs well under a wide range of soil conditions but is not very drought tolerant. Oilseed rape cannot be grown on the same field more than once every three years to prevent the buildup of diseases, insects, and weeds.

Crops for biodiesel demand more than three times as much land as sugar cane used for ethanol to deliver the same amount of biofuel energy. Sunflower and rapeseed lead to much lower biofuel yields per hectare than those for ethanol. The typical yield of soybeans cultivated in Brazil is 600 to 700 liters of diesel equivalent per hectare, while European rapeseed yields are around 1,100 liters of diesel equivalent per hectare.

Palm oil offers an opportunity for expanding the energy supply in developing countries by using it as a biomass resource. Care should be paid to analyze which areas of land are used to supply the palm fruits, as palm oil plantations grown in tropical areas are a major cause of deforestation in countries like Malaysia and Indonesia. Malaysia is the world's largest producer and exporter of palm oil. As with other oily crops, current estimates of fuel yield from palm oil are low: about 900 liters of diesel equivalent per hectare.

Oil-importing countries are considering the production of biodiesel from physic nut or jatropha grown on degraded land. The idea is not to compete with land where profitable food production would be possible. The jatropha tree is indigenous to South America, but it is widely planted in Central America, Africa, and Asia. It is adapted to high temperatures, and it can tolerate drought. The tree is well adapted to marginal soils with low nutrient content. Its cultivation is technologically simple and requires comparatively low capital investment. The oil of the physic nut can be used after detoxification to make edible oil, or it can be converted into biodiesel. Nicaragua is a leading producer of biological diesel substitute based on the oil of the physic nut. ■

Source: *Energy Technology Perspectives: Scenarios and Strategies to 2050.* Paris: International Energy Agency, June 2006. *(Copyright OECD/IEA, 2006)*

SMALL STEPS SAVE BIG IN ENERGY

Mark D. Levine

It is time for policy makers to recognize they can play a more active role in encouraging consumers to invest in and gain from energy efficiency. Steps taken by many individuals can save vast amounts of energy and boost both local markets and the national economy.

Mark D. Levine *is director of the Environmental Energy Technologies Division at the Lawrence Berkeley National Laboratory in California.*

Energy efficiency is usually regarded as a personal activity that can be recommended to individuals but has limited impact on a nation. This is a regrettable misperception. Energy efficiency is not only a tool for achieving energy security; it is the most potent of all the tools in our arsenal. Well-designed and implemented energy efficiency policies can not only substantially reduce energy demand but also give a boost to an economy.

Energy Conservation Versus Energy Efficiency

Energy conservation has come to mean actions taken by individuals to use less energy in carrying out their everyday tasks or even not doing certain activities so as to save energy. There has been only one time when energy conservation was implemented as a serious policy in the United States. This was during the electricity crisis in California in 2001. The state was in a desperate situation: There was no time to build more power plants, and importing electricity from outside the state was not viable. Energy efficiency—as defined below—could not come into play fast enough.

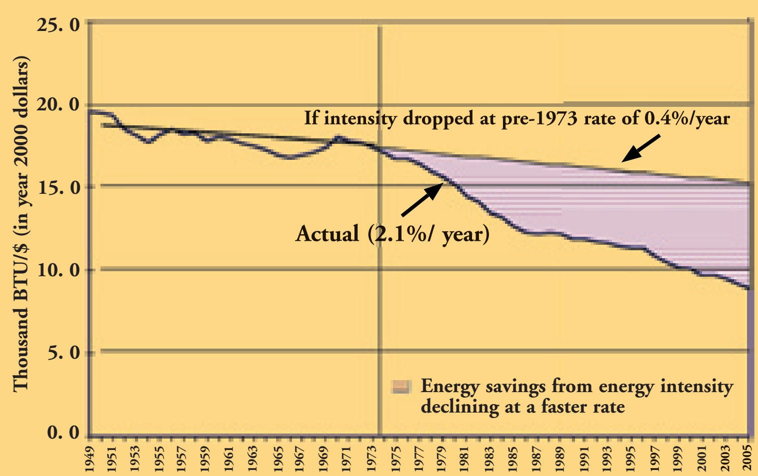
California came up with creative ways of inducing energy conservation, especially the 20/20 program, which gave consumers a 20 percent rebate on their electricity bills if they cut electricity use by 20 percent. During the crucial summer months of 2002, conservation yielded 11 percent electricity and 16 percent peak power savings. The state paid for the savings. But the money stayed in California, going to electricity consumers, and the rebate cost was a fraction of the supply cost, especially at the very inflated prices prevailing at the time.

Energy conservation is not a favored policy except in crisis. The more effective approach involves investment in energy efficiency. Please note the word "investment." Energy efficiency is an investment strategy, and government policy is as important to its success as the decisions of a country's central bank are to its macroeconomic policy. Energy efficiency is not a short-term policy; it is, in fact, effective only if carried out consistently over years and decades.

The Economics of Energy Efficiency

To many people, energy efficiency is either ethereal or so small as to make little difference. People easily relate

Figure 1
Energy Intensity in the United States, 1949 - 2005



Note: British Thermal Unit (BTU) is the amount of heat necessary to raise the temperature of one pound of water by one degree Farenheit.

Source: Derived from data at http://www.eia.doe.gov/emeu/aer/overview.html.

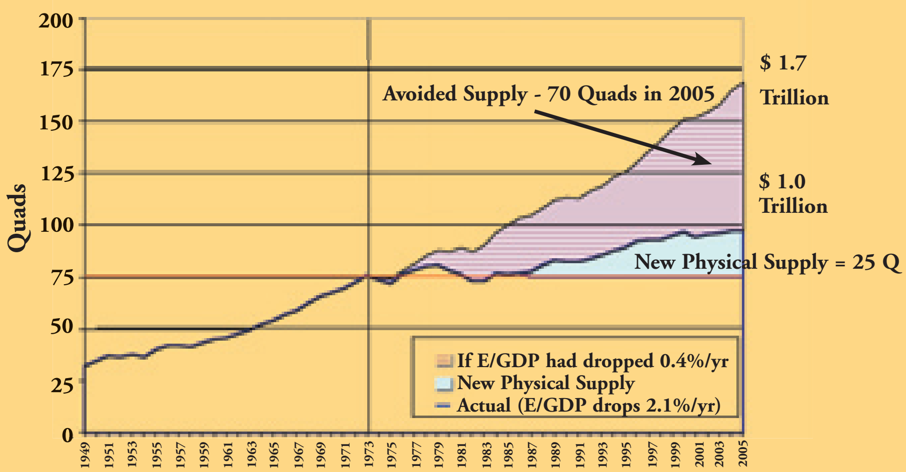
to solar energy installations (for example, photovoltaic on rooftops) or wind energy. But energy efficiency does not lend itself to visualization. And it is achieved through the implementation of many measures, each of which contributes a small amount to reducing energy use.

Because policy makers typically do not recognize the importance of energy efficiency as a policy measure, it often gets ignored. Figures 1 and 2 clarify these points for the United States as a whole. Figure 1 compares energy intensity [energy consumption per unit of gross domestic product (E/GDP)] as it evolved during the three-plus decades after 1973 to what would have occurred if previous trends had prevailed.

Figure 2 shows the dramatic results of this change in energy intensity. If energy demand had continued its earlier growth patterns, we would today be using 75 percent more energy than we are.

The reduction in energy intensity is the result of structural change in the U.S. economy. The shift away from manufacturing toward services such as banking and information technology has contributed about one-third of the intensity gains. Two-thirds is from investment in energy efficiency. This means, remarkably, that energy efficiency contributed almost four times as much as new energy supply in the United States to meeting demand for energy services during the three decades since the 1973 oil embargo. For something virtually invisible and rarely addressed in high circles dealing with energy-security matters, energy efficiency has been a potent force.

Figure 2
Energy Consumption in the United States



Note: Quad is an energy unit equal to 10^{15} BTU.
Source: Derived from data at http://www.eia.doe.gov/emeu/aer/overview.html.

The Five Major Energy Efficiency Policies

The energy efficiency gains in the United States have resulted from four explicit policies and one implicit policy. The four explicit policies have involved these:

- appliance efficiency standards;
- utility demand-side management (DSM) programs (utility investments to increase customers' energy efficiency);
- building-energy standards;
- corporate automobile fuel economy (CAFE) standards.

The implicit policy has been one by which the federal government does not stand in the way of modest energy price increases. That is, unlike other industrialized countries in which energy prices are much higher, the United States does not tax oil to reflect a broad range of external costs.

Of the four explicit policies, three are very actively pursued in the United States. The Energy Policy Act of 2005 set levels that led to 15 appliance standards. The U.S. Department of Energy, under judicial court order, is aggressively pursuing standards that will be issued over the next two to five years for 17 additional products.

DSM—utility programs working to increase energy efficiency on the customer side of the meter—appeared for a time to be stalled because of utility restructuring, but has come roaring back. One of the most successful of the utility DSM programs carried out by many utilities has involved rebates for replacing inefficient fluorescent lighting with efficient lamps.

California utilities will invest $2 billion over three years in DSM, almost double the previous level and quadruple the average over the last decade. According to the utility forecasts, this will cut electricity demand growth from 2 percent per year to 0.5 percent per year over the next decade. California is among the most aggressive states in promoting energy efficiency. Electricity demand growth is expected to be reduced by about 85 percent over the next decade, compared to a projection without the appliance/building energy efficiency and utility DSM programs. As shown by this state's pursuit of electricity end-use efficiency for at least two decades, good energy efficiency investment policies can bring significant results over the long term. This is not widely recognized by the public or by public policy makers.

The third policy involves energy efficiency standards for buildings. Like utility demand-side management, building standards are generally set at the state level and implemented at the local level. As such, performance varies greatly among states. In part because of important achievements in federal research and development (R&D) programs, energy use in new buildings is two-thirds to one-half that of existing buildings, resulting in an assurance of savings over the lifetime of the building.

There are two critical factors necessary to continue this success story: (1) revitalization of the federal R&D effort on energy efficiency in buildings, an effort that produced technology that enabled the energy efficiency improvements; and (2) strengthening of the building energy standards. Several states—especially those on both U.S. coasts—have programs for updating and strengthening standards, but most states do not.

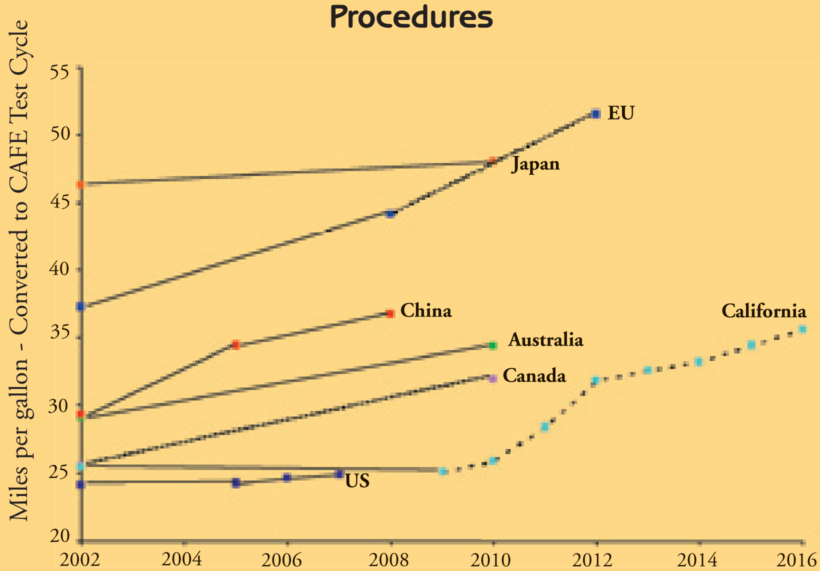
The fourth policy—and the one that is directly related to oil supply security—is auto fuel economy standards. In the long term, the solution to oil imports will require an economically and environmentally viable replacement for oil. But this will not happen soon. Oil imports will continue to rise for the coming decades. While there is universal agreement that the United States needs to cut imports, the problem is not being addressed. This increases our peril in the world.

The problem is not intractable, except perhaps from a political viewpoint. Strengthening corporate auto fuel economy standards, much like appliance efficiency standards, has the beauty of simplicity: It applies to only a small number of manufacturers who can make the required investment to achieve higher efficiency and pass the cost on to consumers. This is also a weakness in the sense that a few strong manufacturing companies can oppose the policy in the U.S. Congress and win the battle. Manufacturers are concerned that stronger fuel economy standards will make consumers unhappy at losing important amenities—in the case of autos, size, safety, and power (acceleration). In fact, prior experience, including the original CAFE standards in the United States in 1975, shows that the industry has been able to innovate and meet what were thought to be tough standards without compromising these characteristics.

Such improvements in auto fuel economy can be achieved to the satisfaction of tens of millions of consumers in other countries. Figure 3 shows the fuel economy standards in the United States and several regions. One wonders, looking at this figure, if there may be some clouds on the horizon for U.S. auto manufacturers in world markets.

The United States can aim to achieve the 2005 European Union level of fuel economy standards by 2015 with all vehicles, including sport utility vehicles

Figure 3
Comparison of Auto Fuel Economy Standards Among Countries, Normalized to U.S. Test Procedures



Note: Dotted lines denote proposed standards.
Source: Feng An and Amanda Sauer, "Comparison of Passenger Vehicle Fuel Economy and GHG Emission Standards Around the World," Pew Center on Global Climate Change, October 27, 2004.

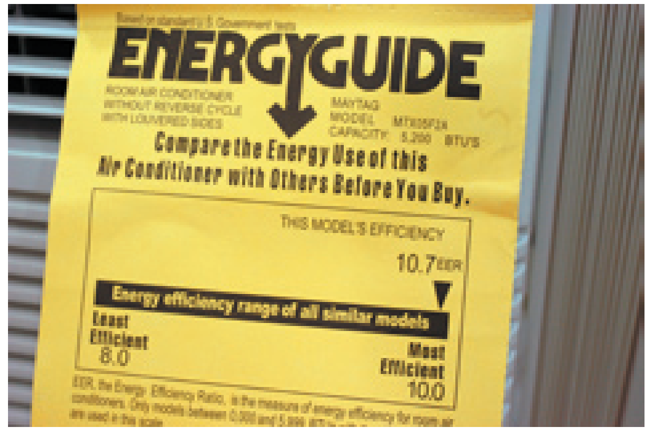
and other light and heavy-duty trucks, having the same percentage increase as automobiles. It could also agree to meet the European 2012 standard by 2020. Although either goal is unlikely to be set by policymakers, the result of such policies, which would still leave us well behind the Europeans, would be to decrease our dependence on imported oil from a projected 56 percent in 10 years to about 40 percent and from 62 percent in 20 years to 25 percent.

For many, the primary motivation for auto fuel economy is energy security. There are other economic, environmental, and safety benefits. The policy is almost certainly cost effective—the energy efficiency investment pays a healthy return. Much like the energy efficiency gains shown for the whole economy in figure 2, such investments in more efficient autos result in very significant benefits to the entire U.S. economy—annual returns of 20 percent or more compared to supply investments that provide no net benefits.

Role for Public Policy

Policies addressing energy efficiency are not adequately recognized as the major tools for increasing energy security. Even though the policies have had only limited attention and support, savings from energy efficiency over the past three decades have yielded four times the impact in meeting demand as new energy supply. Today, America's annual energy bill is $1 trillion. Without earlier energy efficiency, it would be $1.5 trillion!

Energy efficiency is an investment with a well-understood payback. The return on investment is generally high, as long as the policy is well designed and implemented. The financial return from this policy is every bit as certain as the return from an investment in a new oil well or coal mine, only generally better. The big difference between the supply and demand investments is that the former goes to companies that have strong incentives to pursue them. The latter generally are spread among millions of consumers. These consumers are often not aware of the benefits.



William Thomas/Getty Images

A retail store label provides energy-efficiency information on an air conditioner.

Because the energy efficiency investments often are not made without strong policies to promote them and because energy demand growth has very large impacts on the nation, there is a strong case to be made for the role of public policy. Proper policy on energy demand can induce investments from consumers and thus not require government subsidies, unlike some policies that affect energy supply.

It is desirable for energy policy to become a priority for government decision makers, especially those concerned about the energy security of the nation. ■

The opinions expressed in this article do not necessarily reflect the views or policies of the U.S. government.

U.S. HOMEBUILDERS GO "GREEN"

By incorporating off-the-shelf, energy-efficient technologies, homeowners and building managers could cut up to 80 percent of the cost of heating, cooling, and lighting their buildings, according to the U.S. Department of Energy. The potential benefits of using these technologies in the roughly 2 million houses constructed in the United States each year is huge: Nearly 25 percent of U.S. energy consumption is used to power homes.

In 2007, two-thirds of U.S. homebuilders will "build green" in 15 percent of their projects, according to a June study by McGraw-Hill Construction. The study defines building green as going beyond accepted building codes to increase energy efficiency, conserve water, develop building lots in a way that preserves trees and uses the sun, incorporate earth-friendly materials, and reduce job-site waste.

Undine Pröhl/Courtesy National Building Museum

The Tuscon Mountain House with rammed earth walls designed by Rick Joy.

Not long ago, green houses were the province of custom builders. But no more. Pardee Homes, a large-scale builder putting up hundreds of houses in the U.S. Southwest, conforms to high environmental standards in one-third of its projects.

Homebuilders say the biggest reason for building green is customer concern about energy costs. Gasoline prices have increased 86 percent in the last three years in the United States, according to the Bureau of Labor Statistics. Joyce Mason of Pardee says her customers live in suburbs, far from their jobs, and drive a lot. As gas prices rose and they could not easily change their commutes, they looked to save on home energy bills. Mason says her company offers photovoltaic solar systems that might cost as much as $18,000 but will reduce bills by about 70 percent.

The McGraw-Hill study emphasizes builders' use of passive solar heating—situating a home to maximize use of the sun's energy and planting trees to provide shade. Deciduous trees offer shade during summer and lose leaves in winter to allow sun to enter windows.

Builders also are increasingly using low-emissivity windows. According to Donald Albrecht, the lead curator of a year-long National Building Museum exhibit on green houses that opened in May 2006, there are several types of new windows on the market that lock heat or sunscreens between layers of glass. Yet houses featured in the exhibit apply ancient principles in addition to the new technologies. For example, some have bamboo flooring because, unlike wood from hardwood forests, bamboo is a renewable, fast-growing grass.

Thermal mass, another tried-and-true construct, is evident in the thick, rammed earth walls of architect Rick Joy's Tucson Mountain House featured in the exhibit. The walls—like heat sponges—absorb heat during day and release it at night.

A recently built green apartment building in Washington, D.C., requires no advertising, according to designer Russell Katz, because tenants are aware of its financial benefits. "Some people think of living in a green home as being a 'do-gooder,' " says Katz. "In fact, it is business savvy—you really save money."

Katz's tenants pay less than most do for hot or cool air. During construction, Katz cut out such luxury features as marble in bathrooms and stainless steel kitchen appliances in favor of a geothermal system that pipes water from below ground (where the temperature remains a constant 18 degrees Celsius) and blows air over the pipes to heat or cool apartments. "The temperature underground doesn't cost anything," Katz says. The building also has a roof garden that insulates it and manages storm water.

Retailer Home Depot reports that individual U.S. consumers are also renovating homes to conserve. Some of the store's popular items are tank-less water heaters, which save energy and space by heating water as it is used; compact fluorescent lightbulbs, which last 10 times longer and use 66 percent less energy than standard bulbs; programmable thermostats, which save $100 a year on energy costs when used correctly; and additional insulation, an inexpensive way to reduce energy bills.

Some office-tower builders are using the same energy-saving features that homebuilders have recently gravitated toward. "In Germany and Austria, there has been legislation to go more sustainable; as a result they are more advanced and spur innovation," says Albrecht. But citing green high-rises going up in New York City, he notes that "little by little ... Americans are coming on." ■

SAVING ENERGY
An Individual Choice

Over the last several decades, energy prices have been on a roller coaster, often affecting everyday decisions on work, play, and growth. U.S. federal, state, and local governments; businesses; and consumer groups have responded by working together to better educate the public about what individuals can do at a personal level to reduce energy costs.

Following are a few tips for individuals.

Housing

• In hot climates, plant shade trees to cool roofs, walls, and windows. Close blinds or shades in south- and west-facing windows. In cooler climates, allow sun to reach south-facing windows.

• Seal air leaks around doors and windows.

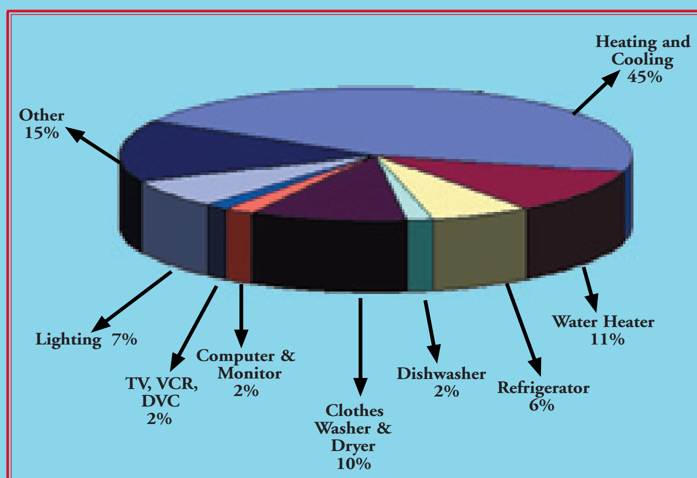
• Use ceiling fans in the summer and winter. By reversing the direction of the blades, warm air is pushed down, helping to keep rooms warm in winter.

• Lower house thermostats in winter; just a one-degree-Fahrenheit reduction can reduce heating costs by about 4 percent. Regularly clean or replace filters in air conditioners and furnaces.

• Consider switching to fluorescent lightbulbs, which last 6 to 10 times longer than incandescent bulbs; add more natural lighting with additional windows.

• Put reflective tiles on roofs and adequate insulation in attics.

• Use low-flow aerating showerheads. Lower the thermostat on the water heater to 49 degrees Celsius (120 degrees F).



Courtesy the Senate Republican Committee

Distribution of electricity consumption in an average U.S. home.

Consumer Products

• When looking for major appliances, buy those labeled with the highest efficiency rating. The electricity savings from today's refrigerator model with a high rating compared to a 1990 model would save enough electricity to light a home for almost five months.

• Use renewable products: bamboo or linoleum in flooring, for example.

• Wash only full loads of clothes. Wash clothes in cooler water, using cold-water detergents. Clean the lint filter in dryers after loads to improve energy efficiency.

• Turn off your computer, monitor, and other electrical devices when not in use.

Transportation

• Avoid erratic driving—quick stops and starts can decrease gas mileage by 33 percent on the highway and by 5 percent in the city.

• Maintain your car. Clean air filters can improve gas mileage by as much as 10 percent. Properly inflated and aligned tires will increase mileage by as much as 3 percent. But using the wrong grade of oil can reduce mileage by 1 to 2 percent.

• Observe the speed limit. In general, every 8.05 kilometers per hour over 96.6 kilometers per hour increases the cost per gallon of gas by 5 to 18 cents per liter at mid-2006 gas prices.

• Avoid carrying extra weight. Every 45 kilograms decreases fuel efficiency by 2 percent.

• Consider buying a hybrid car. The increased gas mileage relative to gasoline-only cars can reduce fuel use by 50 percent or more. ■

Sources: Smithsonian Institution, U.S. Department of Energy, American Society of Interior Designers, Alliance to Save Energy.

CLEAN SOLUTIONS FOR POWER GENERATION

Lewis Milford and Allison Schumacher

Strategies for implementation of low-carbon technologies must be creative to achieve energy security and a stable climate by 2050. This planetary energy transformation must include a mix of clean technologies such as decarbonized coal, carbon sequestration, fuel cells, bioenergy, and ultra-efficient gas powered plants.

Lewis Milford *is president of and* ***Allison Schumacher*** *is project director at Clean Energy Group, a leading U.S.-based nonprofit advocacy organization working on innovative technology, finance, and policy programs for a variety of clean energy and climate change issues.*

Unprecedented, massive innovation must take place to develop, commercialize, and bring to market and to large-scale deployment low-carbon technologies that will revolutionize the world.

Clean energy markets have grown tremendously in recent years, but represent only a fraction of a solution to global warming, which depends on a radical transition to a low-carbon future.

Clean energy has usually included the conventional renewable technologies: energy production from solar, wind, small hydro, biomass, ocean thermal, tidal and wave, geothermal, fuel cells, and related energy storage and conversion technologies.

But comprehensive, low-carbon-technology innovation is needed. We must massively increase use of these renewable technologies and significantly advance low-carbon options such as decarbonized coal, carbon sequestration, ultra-high-efficiency fossil energy production, fuel cells, bioenergy, and derivatives of genomics, nanotechnology, and related fields.

Moreover, today's energy and climate policies alone cannot drive clean energy markets at the scale or pace necessary to solidify energy security and stabilize the climate by 2050. We must be more creative in deploying new, innovative strategies for all these low-carbon options. Also, current structures for financing and commercializing innovative technologies are failing to deliver these much-needed low-carbon technologies to market.

Only by simultaneously tackling the twin challenges of accelerating the pace of low-carbon technology innovation and creating broad-scale financing and commercialization can we achieve a planetary energy transformation.

Low-Carbon Technology Solutions

In addition to renewables—such as solar photovoltaics, wind, ocean energy—and efficiency technologies, promising low-carbon technology solutions include the following:

Decarbonized coal: Integrated Gasification Combined Cycle (IGCC) represents a new generation of coal plants that are technologically superior and environmentally preferable to conventional plants. This is due to their ability to gasify coal, thereby reducing the levels of oxides of sulfur, oxides of nitrogen, particulates, and mercury emissions before combustion. IGCC plants also significantly reduce carbon dioxide emissions and can be further configured to capture carbon, eliminating the final cleanup.

Coal can be decarbonized three ways—through end-of-pipe scrubbers, sequestration, and IGCC (or IGCC plus sequestration). The three methods of decarbonization are already available commercially, but they need to be produced and deployed in large quantities to compete with and put a stop to new construction of conventional coal plants. This is especially true in developing countries, where the projected growth in conventional coal plants is very high. In a future carbon-constrained world, IGCC could become the coal plant of choice.

Ultra-efficient gas power plants: Natural gas plants that utilize advanced combined-cycle turbines have higher efficiency and produce less greenhouse gas emissions than conventional coal plants. At various times in 2005, natural gas was a more expensive and volatile fuel than coal, making cost/economics a critical factor. How future supplies of natural gas develop may affect any cost differential. Incen-

A 250-kilowatt fuel cell, part of the system that generates electricity and heats water for a Sheraton hotel in New York.

AP/Wide World Photo

tives to increase cost competitiveness may be needed to encourage widespread use of ultra-efficient gas technology.

Fuel cells: Fuel cells convert hydrogen and oxygen into electricity, with only water and heat (no greenhouse gases) as by-products. They are a promising technology for multiple applications, especially for producing clean, distributed power on site at locations with sensitive power loads, such as airports, banks, data centers, first responder stations, hospitals, and telephone switching stations.

On-site fuel cells offer energy security with sustained, high-quality power. They can operate on natural gas as well as renewable fuels. Barriers to fuel cell technology include relatively high upfront capital cost, maintenance and operation requirements, the cost of producing hydrogen fuel, and fuel storage and delivery issues. In order to achieve widespread adoption, fuel cells should be considered for critical sites such as hospitals and other places where power disruption can have severe consequences. For those types of facilities, the cost differential may be less of a barrier. Other barriers to greater penetration of fuel cells at the utility level, such as exorbitant rates charged to tap into the power grid when a fuel cell is shut down for maintenance, must also be overcome.

Cellulosic biomass and biofuels: As interest in the production and use of biofuels rises, there is more use of biomass technologies, such as anaerobic digesters and gasifiers, to make power from crops, crop waste, and manure. However, the bioenergy market is relatively nascent and has a way to go to reach the point that signals the rapid and widespread adoption of biomass and biofuels technologies. Further, from a low-carbon perspective, it is widely recognized that using cellulosic (plant-based) biomass is preferable to growing dedicated crops, such as maize, to produce biofuels because harvesting and transporting the dedicated crops increases carbon dioxide emissions. Genomics research may be critical to advance this technology, but it has yet to be harnessed to develop and commercialize high-energy-producing biofuels and energy systems.

Sequestration: Sequestration—capturing and locking away excess carbon emissions rather than releasing them to the atmosphere—falls into two categories: (1) biological, in which the carbon is captured in plants known to absorb a lot of carbon and planted in specific areas; and (2) geological, in which carbon is injected into rock formations. A host of technologies is being explored for both types of sequestration, but none is yet available on a widespread basis. All actors, public and private, should take more aggressive action to address quickly the various scientific and technical questions regarding how best to store and capture carbon for long periods of time.

There are probably many other low-carbon technologies yet to be invented that could disrupt the status quo of more traditional energy technologies. The challenge lies not only in the invention, but also in establishing and rapidly expanding the markets for future low-carbon technologies.

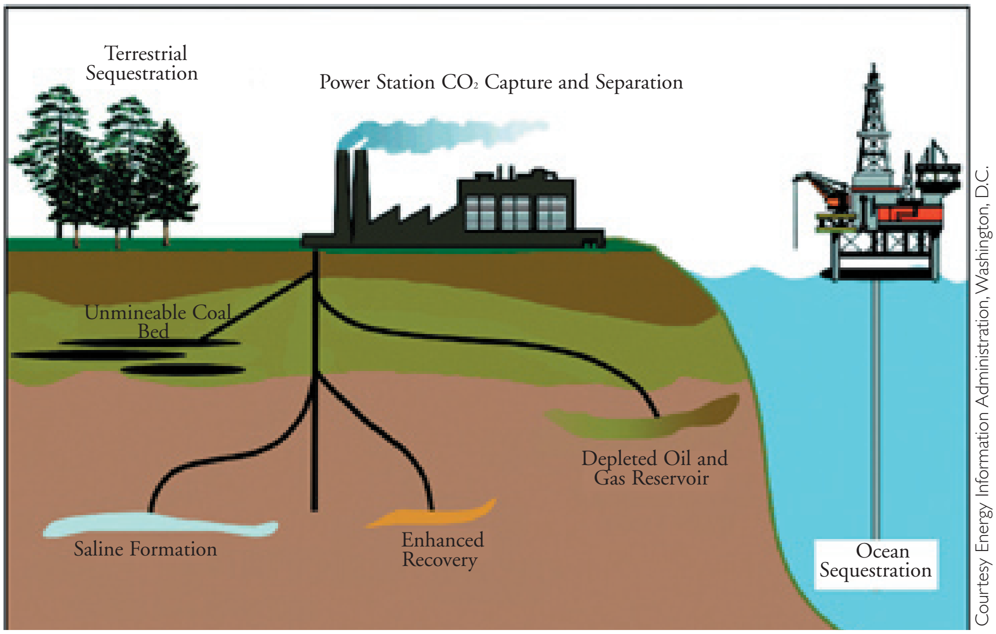
Accelerating Innovation

There are multiple low-carbon technology challenges and opportunities on the horizon. Experts agree that successful development of clean energy will require attention, not just to advances in basic and applied sciences, but also to the commercial dynamics that surround emerging technologies.

The Group of Eight (G8) countries recognized this pressing need for technology innovation and its commercialization when it launched the G8 Dialogue on Climate Change, Clean Energy, and Sustainable Development at Gleneagles, Scotland, in July 2005. The World Bank developed an "investment framework" to serve as a cornerstone for this dialogue, acknowledging the critical need for technology innovation to support a massive scale-up in investment, research and development, and commercialization of low-carbon technologies.

The World Bank's investment-framework report concludes that the current policies and funding from public

Carbon Sequestration Options



Carbon dioxide (CO_2) captured from emissions or removed from the air can be stored long term in vegetation, soil, and underground reservoirs; injected deep into oceans; or converted to rock-like solid materials. Compressed CO_2 can be used to enhance recovery of oil from oilfields and methane from unmineable coal beds. Once used for this purpose, CO_2 remains safely and permanently stored beneath the Earth's surface.

and private sources are not enough to promote technologies that will reduce carbon to stabilize emissions.

CHALLENGES OF ENERGY TRANSFORMATION

Transforming the world's energy system will be tremendously difficult. It is the most capital-intensive industry in the world, a complex and interdependent financial, regulatory, and institutional network with over a century of incumbent protection and support. However, an energy revolution can be swift: The car replaced the horse as a mode of transportation in about 30 years, while central electrification diffused throughout the United States in fewer than 40 years.

The transformation at hand will need to be equivalent in scale to the energy-fueled technological transformation in the industrialized nations over the last 100 years. This was a period that saw a transition from waterwheels for industry, wood and kerosene for domestic use, and horse-drawn transportation to near-universal electrification, the dominance of coal for electric production, millions of gas- and diesel-fueled vehicles, jet travel, and, eventually, the microchip and the digital economy it spawned.

To achieve a transformation on a similar scale, several changes must take place:

- Of the utmost importance, the government, academia and the private sector should coordinate research and development (R&D) *with* deployment and technology commercialization, rather than treat R&D as a sole area of focus.
- Debate on low-carbon technologies should take place at various levels (international, subnational) and within many frameworks for subnational stakeholders, as well as the United Nations Framework Convention on Climate Change and the G8 Dialogue on Climate Change, Clean Energy, and Sustainable Development.
- The task of reducing carbon emissions on a global scale should be distributed to all levels of the public and private sectors. This would open the door to the kind of creative problem solving that would address market shortcomings, promote low-carbon technology transfer and information sharing, foster linkages among disciplines, and produce real results.
- Energy finance must shift aggressively toward new forms of capital accumulation to build the low-carbon energy infrastructure of the future.
- The G8 investment framework and other forms of international collaboration must answer broader questions on technology innovation and commercialization. Gaps in the innovation chain must be filled in order to shift to low-carbon technologies in both industrialized and developing countries. To produce results, this must be coupled with a significant expansion of resources and distinct budgets. Public-private partnerships need to make it a top priority to accelerate the pace of low-carbon technology innovation and adoption.

Comprehensively addressing these issues is the energy security challenge of the 21st century. ■

The opinions expressed in this article do not necessarily reflect the views or policies of the U.S. government.

COGENERATION
More Energy, Less Pollution From Fossil Fuels

Cogeneration has been known since inventor Thomas Edison applied the idea in 1882 in the first U.S. power plant. The process uses a by-product of electricity to also provide heating and cooling. It was only quite recently that the U.S. government and environmental groups embraced this and other integrated energy systems as one of the best ways of improving energy efficiency and reducing air pollution. Cogeneration and trigeneration, which includes also cooling, reduce energy costs and improve power reliability and quality.

Currently used to power some commercial buildings and industrial facilities, these systems convert 80 to 85 percent of fuel's energy content into usable energy, compared to 50 percent at conventional thermoelectric stations and only 33 percent for power generation in general, according to the Midwest Cogeneration Application Center. Increased efficiency of energy utilization reduces the amount of fossil fuels consumed per unit of energy used, cutting by 45 percent air emissions that would come from conventional power plants.

Yet the concepts of combined cooling, heating, and power (CCHP) generation, as trigeneration is known, and combined heat and power (CHP) generation, as cogeneration is known, have failed to create the same excitement and interest as, say, hybrid cars. The share of power generation from integrated systems and renewables in the global market has increased only slightly, going from 7 percent in 2002 to 7.2 percent in 2005, according to a survey by the World Alliance for Decentralized Energy (WADE).

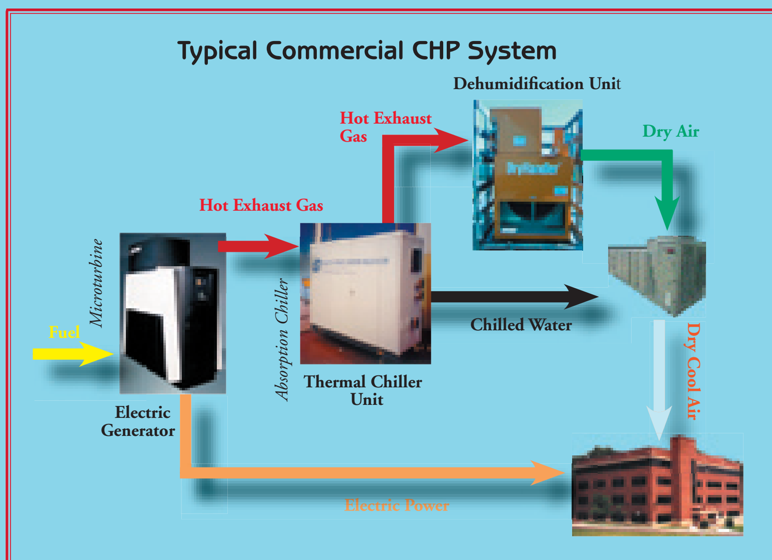
WADE blames this slow growth on "persistent" regulatory barriers and the high prices of natural gas, the second most used fuel in the integrated systems after coal. Some experts, however, argue that the lack of one-stop shopping for the integrated systems and the incompatibility among parts from different manufacturers have hampered the expansion.

A cogeneration system consists of an engine, turbine, or fuel cell that generates on-site electricity, and a heat recovery unit that captures waste heat from the generation process. In commercial buildings, cogeneration systems are usually connected to an absorption chiller that provides heating and cooling for the central heating, ventilation, and air conditioning systems.

Experts predict a more positive outlook for cogeneration in coming years, thanks to standardized parts and preassembled modular systems. According to David Engle, a writer specializing in construction topics, the new generation of cogeneration systems will transform the integrated energy industry and broaden the potential customer base to hospitals, nursing homes, data centers, food-processing plants, supermarkets, warehouses, hotels, and educational facilities. Facility operating costs will dive as equipment prices drop and energy efficiency rises, he says in a 2005 article published by the journal *Distributed Energy.*

WADE believes that growth potential in emerging markets is greater than prospects in the developed world. In India alone, integrated systems have the potential to cogenerate enough electricity from by-products of sugar-cane processing to become a major player in satisfying that country's growing demand for electricity, according to Winrock International, a nongovernmental organization that works on natural resource and environmental issues. And in Brazil, new gas discoveries off the southeast coast, coupled with relatively new regulatory incentives, provide opportunities for cogeneration investment in São Paulo and Rio de Janeiro, according to WADE.

WADE says that future market prospects for cogeneration everywhere depend on removing regulatory barriers in the electricity market and creating a level playing field for all forms of electricity generation. ■



Courtesy Midwest Combined Heat and Power Application Center

Electric generator/microturbine provides different energy functions within a building.

DEVELOPING MARKETS FOR CLEAN ENERGY TECHNOLOGIES

Larisa E. Dobriansky

AP/Wide World Photo

A researcher at Argonne National Laboratory watches a Lexus hybrid car being tested.

***Larisa E. Dobriansky** is Deputy Assistant Secretary of Energy for National Energy Policy.*

Governments can play a critical role in facilitating clean energy technologies in the marketplace by providing financial incentives and removing market barriers to release the potential of technological innovation.

The challenges to achieving a secure and sustainable energy future are both large and urgent. If recent trends are to continue, global energy demand is projected to increase four times today's level, entailing high costs, greater oil import dependence, worse local and regional air pollution, and higher risks of climate change. Moreover, in the next two decades, more than half of global energy growth will be in developing and transitional economies, as these nations continue to improve their standard of living. The magnitude of these realities calls for changing the course of world energy development through technology innovation and commercialization. Without massive and global technology development and deployment, such rapid growth in total world energy use will compound the energy-linked problems and challenges already of great concern today.

We have a critical window of opportunity to move the world off its current path and to embark on a trajectory toward a new global energy economy that will at once enhance energy security and economic growth and significantly improve the environment. Substantial investment in energy infrastructure will be required to meet the anticipated growth in demand. Moreover, to transition to cleaner, more efficient energy technologies and to mobilize the necessary private capital to bring the technologies to commercial scale will entail well-designed policies and incentives, effective public-private partnerships, and international cooperation.

Government, therefore, has a crucial role to play in influencing the conditions in the marketplace for adoption and diffusion of cleaner, more efficient technologies. Within today's more competitive, integrated, and efficient global markets, this role becomes one of an enabler and catalyst. Where there is the potential in the marketplace for net public benefits from using better energy technologies, government can increase the prospects for adoption by focusing on making the energy-related attributes of these products more attractive to suppliers, consumers, and investors, while minimizing interference with market processes.

The Bush administration is pursuing a comprehensive approach to facilitating market development for energy technologies that will be the building blocks for transforming energy systems globally—an approach that accounts for all aspects of the innovation process. The administration's programs and policies are seeking to accelerate innovation, reduce market barriers, create demand for clean energy services by increasing consumer choices, and improving energy production and consumption systems through better rules and institutions. This multifaceted, economic development approach to technology innovation focuses on building viable markets, domestically and internationally, that will attract investment in less energy-intensive products, cleaner and more energy-efficient processes, and production modernization. It is a pathway that combines technology innovation, investment mobilization, and market-based policy development.

"Using the globalizing forces of technology, information, and capital, governments at all levels can help to foster creative business solutions for assuring reliable, affordable, efficient, and clean energy."

Technology Innovation Process

On January 31, 2006, President Bush announced his Advanced Energy Initiative to reduce U.S. dependence on foreign sources of energy and move beyond a petroleum-based economy. To change how we power our homes and offices, the U.S. government plans to invest more in zero-emission coal-fired plants, revolutionary solar and wind technologies, and clean, safe nuclear energy. To change how we power our automobiles, the initiative will increase research in better batteries for hybrid and electric cars and in pollution-free vehicles that run on hydrogen. It also provides funding for additional research in cutting-edge methods of producing ethanol, not just from maize, but also from wood chips, leaves and stalks, or switch grass.

This initiative, as well as other research, development, and deployment programs and activities undertaken during this administration, have emphasized the interactive learning process essential to technology innovation that aims to achieve technical improvements and cost reductions, as well as business and market organizational changes needed to fit the characteristics of the technology. The federal government is playing a pivotal role in encouraging private investment and activating learning processes among all relevant market participants. Toward the goal of technology deployment, the government interacts with the private sector to stimulate technology learning that can progressively reduce costs and lead to product refinements and to develop the ability of market participants to produce and use technologies more cheaply and effectively.

Procurement and niche market development have been two key deployment strategies to motivate learning investments from private sources and to stimulate organizational learning among market actors. Procurement through, for example, the Federal Energy Management Program, which brings together technology developers, customers, and intermediaries in the chain of supply, is facilitating changes in the way market participants are doing their business, in how they are relating to one another, and in their capability to produce and consume products that are cleaner and more efficient. Similarly, in focusing on specific characteristics of new technologies that are of special interest to certain buyers, niche markets have helped to set into motion learning processes and attract investment in technology development. In particular, the Department of Energy (DOE) is coordinating with the Department of Defense on expanding use of domestic energy sources (coal, biomass, heavy oil sands, and oil shale) for production of new low-emission transportation fuels for military and civilian use. This coordination will foster research, development, demonstration, and commercial use of such technologies as coal gasification, biomass energy conversion, and syngas-to-liquids technologies (converting natural gas- and coal-derived synthetic gas to liquid fuels and chemicals).

Market Barriers

Relying principally on market forces, the administration has sought to intervene only in situations where the market fails to allocate resources efficiently and the intervention will improve net social benefits.

Market barriers slow the rate of uptake of new and improved technologies and create inertia based on conventional technologies. Typical barriers include lack of information, uncompetitive market prices or price distortion, high transaction costs, lack of access to financing, capital stock turnover rates, inefficient market structures, and excessive or inefficient regulation.

The federal government is implementing a wide array of policies that adjust for factors such as pollution that are not accounted for in the market and not reflected in prices, or that make legal/regulatory changes in market organization and structure. Market prices have been adjusted to incorporate these factors through taxes, standards, and regulations that force sellers and buyers to take into account costs that are external to the market. Minimum energy performance standards, for example, have been a very cost-effective means for displacing inefficient products with energy-saving ones in the marketplace. Under the Energy Policy Act of 2005 (EPACT), new energy efficiency standards will be established for many appliances and for office equipment, including compact fluorescent lamps, dehumidifiers, refrigerated beverage-vending machines, unit heaters, ceiling fans, commercial air-conditioning and heating equipment, commercial ice makers, and commercial clothes washers.

The U.S. government also is implementing a variety of performance-based and investment-based incentives and has established reliable information systems that disclose the benefits of energy efficient products. With Energy Star product labeling, the federal government has set energy efficiency guidelines for more than 40 commonly purchased home and business products. In 2005, the program led to energy savings of 150 billion kilowatt-hours (about 4 percent of U.S. electricity sales), resulting in utility bill savings of $12 billion and preventing 35 million metric tons of greenhouse gas emissions.

Courtesy the Environmental Protection Agency

The Energy Star logo.

EPACT also provides a wide array of incentives for clean energy technologies, products, and services, including tax credits and deductions; energy savings performance contracting; credit to holders of renewable energy bonds; and funding for state-run rebate programs for Energy Star products. The act also authorizes DOE to issue loan guarantees for new and improved technologies. This financial instrument can be targeted at the risks-discouraging investment by first adopters of advanced technologies to address a significant gap in the development cycle with respect to "getting to market." Use of loan guarantees can significantly leverage private resources. The EPACT incentives will help to overcome market barriers and allow for market growth that would not otherwise have occurred but for the policy steps.


Courtesy the Environmental Protection Agency

An energy-efficient compact fluorescent lightbulb.

MARKET TRANSFORMATION

Market transformation programs are helping to raise the profile of energy factors in market activities and affect the institutional framework within which the markets operate, with minimal interference with normal market processes.

The Federal Energy Management Program, for example, is developing markets for energy-efficient technologies, products, and services through a mix of policy tools and incentives, including standards and labels; performance/savings targets; government purchases; energy audits by energy service companies; consumer education and information; energy pricing policies and metering practices; research, development, and demonstration of new technologies; public-private partnerships; and innovative financing, especially energy savings performance contracts and public benefit funds.

Through the Partnerships for Home Energy Efficiency presidential initiative, DOE, the Environmental Protection Agency, and the Department of Housing and Urban Development are collaborating with the private sector to improve the access of homeowners and others to energy efficient products and services. This initiative also aims at overcoming market barriers by better aligning policies and incentives to market structures in order to address bottlenecks to the uptake of efficient energy and renewable technologies.

Creative Business Solutions

Taken together, these efforts represent a holistic approach to market development that combines technology innovation, investment mobilization, and policy development. Through partnerships and networks, this approach seeks to develop market relationships in which different participants at different levels, whether local, state, federal, regional, or international, operate in a mutually reinforcing manner and leverage one another. The aim is to develop mechanisms for greater cooperation and coordination to advance the social process of innovation. Using the globalizing forces of technology, information, and capital, governments at all levels can help to foster creative business solutions for assuring reliable, affordable, efficient, and clean energy to power economic growth and development in the future. ■

A ROAD MAP TO INVESTING IN SUSTAINABLE ENERGY

Steven Parry, Mark Cirilli, and Martin Whittaker

AP/Wide World Photo

Schoolchildren walk under wind turbines in Pennsylvania.

A well-designed regulatory environment and a solid financial infrastructure are required to support large-scale implementation of clean energy technologies. International organizations, governments, and private financial and risk management providers are seeking ways to participate in this monumental task through creative financing mechanisms and alternative investment vehicles.

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Despite the flood of stories on climate change and the technology boom in the energy sector, little is reported on how we are going to finance the implementation of new technologies. The scale of this issue may dwarf the technological challenges—the International Energy Agency estimates a need for $17 trillion to finance global energy expansion, including clean energy projects, over the next 25 years. Some $5 trillion will be required in developing nations alone.

Sources of Energy Finance

Finance for sustainable energy is either company or project related. It can be provided at any phase of project development, from the earliest stages, where risks and return expectations are high, to the later stages of mature operation, where risks and returns are commensurately lower. A chart illustrates the roles these sources of finance play.

High — **Risk & Returns** — Low

Company

Development Stage	R&D/ Seed	Start-up	Early-Stage Growth		Late-Stage Growth		Mature			
Investment Vehicle	Angel Investors	Venture Capital	Private Equity	Bridge/ Mezzanine	Public Equity	Structured/ Project Finance	Corporate Bonds	Mutual Funds		

Project

Development Stage	Siting	Data Collection	PPA	Installation	Operation
Investment Vehicle	Developer Equity		Traditional Project Finance—Senior and Sub-Debt		

At the company level, sources of capital include these:

- individual, or "angel," investors and venture capitalists at the highest risk, early stage of company development where research and development (R&D) and start-up capital is required;
- private and public equity investors, who usually enter the field once revenues are established to provide growth and expansion capital;
- secured and corporate debt for late-growth-stage and mature companies with established history and balance sheets.

At the project level, development is funded via these:

- project equity, which is provided early in the project cycle for siting, data collection, and project formation and which confers ownership interests to the investors, who then become shareholders in the enterprise;
- mixed debt and equity, also known as "mezzanine finance," which is typically provided for the construction or installation of the project;
- senior debt, provided for the construction of larger projects and the ongoing expansion and operation of the project enterprise, and usually supplied in the form of traditional project loans offered by major institutional lenders requiring conventional interest and principal repayments over the term.

The scale of the project also impacts the source of capital. Large projects based on established technology, such as hydroelectric power or onshore wind power, are traditionally funded by large financial institutions and require pools of debt, mezzanine, and equity financing from multiple sources. In such projects, risk is both measurable and can be insured. Frequently, these projects are financed "off balance sheet," meaning that those loaning money to the project cannot recoup their loss through claims on the project owner if the project fails.

Smaller-scale projects or projects utilizing new technologies, such as solar power and small-scale biomass, are different. These forms of energy technology involve a technical risk in addition to the risks associated with all energy projects, so they tend not to attract the traditional sources of capital from private markets. Financing in such cases is usually provided in the form of equity because lenders generally view the cash flows to repay debt as being high risk, the perception that makes them reluctant to extend loans. Thus, solving the risk challenge is critical to bringing sustainable energy production up to meaningful volumes.

> "Technology improvements are rapidly driving down the costs for sustainable energy technologies ... The question remains whether the financial infrastructure will be in place to support significant rollout of new technologies as this happens."

Assessing Risk

Financing sustainable energy technologies necessarily entails taking risks. Some of these are typical for the energy sector, while others are particular to sustainable energy technology and the myriad technical, performance, regulatory, and contractual issues that surround it. These risks include the following:

- pricing—uncertainties of project economics in the face of deregulation and the trend from long-term contracts to short-term, or "spot," power pricing, where pricing and payment occur at or near the same time;
- currency risk—exposure to adverse exchange rate movements against assets held in foreign currencies;
- country/political risk—potential for governments to renege on the power purchase agreements (PPA) that provide the long-term revenues for power projects against which debt and mezzanine financing are supplied;

• poor insurability—lack of underwriting experience and historical data on loan loss, which renders insurance expensive and limits coverage;

• technical performance—lack of historical performance data and scarcity of proven operators;

• intellectual property (IP) protection—potential for patent infringement and IP theft in developing markets;

• servicing and maintenance—lack of specialized engineering services, skilled labor, and replacement equipment;

• primary resource availability—uncertainties over, for example, wind performance, biomass feedstock sourcing, and hydro availability;

• infrastructure risks—grid connectivity problems and lack of access to transmission and distribution systems;

• credit risk—poor credit quality of many smaller project developers and power contract counterparties;

• contractual risk—immaturity of legal environment surrounding clean technology;

• regulation and public policy—changes in political attitudes toward tax incentives for clean energy technologies (for example, uncertainties over investment tax credit and production tax credit extensions in the United States).

Courtesy Polyene Film Industries Limited, Chennai-Hyberabad
(c) ASTAE 1998/ World Bank

Solar powered pump in India installed as part of an Indian Renewable Energy Development Agency project.

Mitigating Financing Risk

Today, many of these risks are poorly understood or inadequately addressed in the marketplace. As a result, many mainstream finance providers feel unable to back sustainable energy technologies over more traditional investments. These financiers believe—often erroneously—that sustainable energy financing is a socially motivated pursuit that is inconsistent with their fiduciary duty to pursue the best risk-reward combinations.

Recently, a number of alternative investment vehicles have emerged that target sustainable energy financing and that are comfortable with the attendant risk equation. This has given rise to significantly enhanced levels of investment by the venture capital community in the broader clean technology category, which includes sustainable energy. Venture capital firms now direct 10 percent of their annual investment total to clean technologies. Companies such as SunEdison LLC are pursuing a fee-for-service model—providing the initial capital for solar projects in exchange for monthly billing to the customer. This surge of commercial innovation is coinciding with other trends—record high volatility in fossil fuel markets, technology advancement, power market regulatory reform, and deepening environmental concerns—to make investing in sustainable energy increasingly attractive.

Currently, however, the vast majority of initiatives still require a combination of regulatory and third-party participation. In developing countries and economies in transition, key players in this quasi-public-private partnership approach include multilateral organizations such as the World Bank and its financing arm, the International Finance Corporation; bilateral organizations such as the Export-Import Bank of the United States; and unilateral national programs. In the United States, Canada, Asia, and Europe, governments pursue risk mitigation through tax subsidies, direct and indirect financial support, and the use of market mechanisms. Some important examples include these:

• the Indian Renewable Energy Development Agency, which is providing financial assistance to solar projects;

• the World Bank's Asia Alternative Energy Program, which has contributed more than $1.3 billion to sustainable energy programs;

• investment tax credits and production tax credits in the United States, which provide capital and operating-cost tax offsets to lower the unit costs of sustainable energy production;

• the Carbon Trust, an independent company set up and funded by the government of the United Kingdom to help the country move to a low-carbon economy;

• Sustainable Development Technology Canada, a multimillion dollar foundation established by the government of Canada in 2001 to foster the development and demonstration of clean technologies.

Future program opportunities, particularly for small-scale projects, include development of new forms of insurance, such as price protection programs and bundled energy purchase derivatives that provide buyers and sellers of power with greater price certainty, innovations in financing, and, finally, securitization of clean energy risk. Programs at the national level designed to help finance end-user sustainable energy projects are beginning to appear as well.

Ultimately, none of these programs will succeed without a favorable and well-designed regulatory environment. Countries will succeed only where the rules are consistent and long term, where protection of intellectual property is assured, where contracts are honored and regulations are enforced, and where financial support for sustainable energy projects includes long-term pricing clarity.

The Carbon Finance Alternative

Environmental market mechanisms that attach a financial value to the environmental benefits created by clean energy projects are proving to be an effective means of catalyzing additional financing. In particular, cap-and-trade-type emissions markets—where total emissions across a number of regulated entities are capped but individual entities are free to trade among themselves to meet their own targets at lowest economic cost—have diverted hundreds of millions of dollars into clean energy projects and given rise to entire industries dedicated to the monetization of emissions credits. Project-based programs—in which emissions credits are awarded to projects in amounts equal to the quantity of emissions avoided relative to a baseline business-as-usual scenario—have also proved to be effective at diverting capital to clean energy projects.

Some successful programs are the U.S. cap-and-trade sulfur dioxide allowance program, the European Union's Emissions Trading Scheme, and the Kyoto Protocol's Clean Development Mechanism and joint implementation schemes. Over time, these markets have the potential to materially alter the economics of power generation in favor of clean energy and emissions-reducing technologies. The trading of renewable energy certificates (RECs) or their equivalent ("green tags") is a similar market that creates additional cash for qualifying clean energy projects based on the sale of units of renewable power (typically one REC equals one megawatt hour of renewable energy-based electricity) to wholesale power producers regulated under renewable portfolio standards (RPS). In the United States, several states, including Texas, New Jersey, and the New England states, have adopted, or are in the process of adopting, REC trading programs. Regulated utilities in Connecticut, Maine, Massachusetts, and Rhode Island are allowed to satisfy their RPS requirements by purchasing RECs from renewable power generators anywhere within the New England Power Pool.

Transition to a New Era

Technology improvements are rapidly driving down the costs for sustainable energy technologies toward price parity with traditional sources of energy. The question remains whether the financial infrastructure will be in place to support significant rollout of new technologies as this happens. The financial and risk management providers are actively seeking ways to participate in the monumental task of supporting these new technologies, but they will do so only when the rules are clear, when government policy makers provide long-term commitments, and when the risks are appropriately balanced with rewards. The successful countries will be those that provide this clarity with long-term, thoughtful regulatory environments and stable, risk-mitigated financial markets. ■

The opinions expressed in this article do not necessarily reflect the views or policies of the U.S. government.

ENERGY SECURITY AS A GLOBAL PARTNERSHIP

Paul E. Simons

In a world of increasingly integrated energy markets, countries can ensure their access to reliable, affordable, and environmentally sound energy only by working in a variety of international partnerships.

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The fundamental objective of U.S. energy policy is to ensure that our economy has access to sufficient, affordable, and reliable energy supplies on terms and conditions that support economic growth and prosperity. However, due to the globalized nature of the oil market and the increasingly integrated natural gas market, events that negatively (or positively) impact the energy security of any country can affect the energy security of the United States, and vice versa. A pipeline attack in Nigeria, tension over Iran's nuclear program, burgeoning economic growth in China and India, and natural disasters like Hurricane Katrina are issues that have direct impacts on global energy security. Therefore, the best way to strengthen U.S. energy security is to take steps to strengthen global energy security. How can this be achieved? One important element is an active process of outreach and energy diplomacy that the United States has pursued for more than 30 years.

As the world's largest producer and consumer of energy resources, the United States must play a leading role in addressing the world's energy challenges and ensuring a secure energy future. Ensuring our national energy security requires well-coordinated international efforts given the increasingly integrated nature of the world's energy markets. It also implies that the global community has a responsibility to ensure adequate, affordable, and reliable energy supplies and services. To advance this goal, the U.S. international energy security policy draws on four key elements:

- promoting the diversification of energy sources and supplies, worldwide;
- working with other oil consuming countries to respond to supply disruptions, particularly through the use of strategic petroleum stocks;
- pursuing dialogue with major oil-producing countries to maintain responsible production policies to support a growing world economy and to reduce oil market price volatility;
- working with other countries to reduce global dependence on oil, by promoting greater energy through efficiency and the development of alternative sources of supply.

Diversification of Energy Supplies

The U.S. government has taken a number of steps over the years to promote the diversification of energy supplies and transit routes. Although the Middle East dominates—and will continue to dominate—world oil markets, the development of new supplies in a number of other regions in the world is an important objective. The United States imports energy from a diverse array of suppliers, including Canada, Mexico, Saudi Arabia, Venezuela, Nigeria, Angola, Russia, and the United Kingdom. We are actively engaged with these and a broad array of other countries in order to foster diversity of sources of energy supply and modes/routes of transit so as to lessen the impact of supply disruptions, whether they are natural or man-made.

Europe

We are working with the European Union (EU) on broad and deep cooperation on energy security, announced at the 2006 U.S.-EU Summit, of which a key element is work on diversification of energy sources and supplies. Among other steps, we will jointly engage with key energy producers and consumers to encourage their diversification efforts, coordinate to provide technical assistance to improve legal and regulatory frameworks for energy in third countries, support maintenance and improvement of pipeline infrastructure to ensure delivery capability, encourage investments in energy diversification,


AP/Wide World Photo

U.S. Energy Secretary Samuel Bodman, second right, shakes hands with Turkish President Ahmet Necdet Sezer as Georgian President Mikhail Saakashvili, second left, looks on and Azerbaijani President Ilham Aliyev, right, applauds during an inauguration ceremony of the Baku-Tbilisi-Ceyhan pipeline in Azerbaijan in May 2005.

and analyze geopolitical developments in key energy producing and consuming countries to coordinate responses. In addition, since 2002, U.S.-funded technical assistance programs have supported the Energy Community Treaty for Southeast Europe, which is aimed at creating electricity and gas markets in the energy transit countries of Bulgaria, Romania, Serbia, Macedonia, Bosnia, and Albania, with the added participation of Greece, Italy, Austria, Moldova, and Hungary.

Caspian Region

A major U.S. foreign policy priority since the mid-1990s has been the development of multiple pipelines to provide for the export of oil and gas from the Caspian region to the rest of the world. The Caspian Basin represents one of the most significant new sources of non-OPEC oil in recent years, and production should continue to grow in coming years. In addition to enhanced energy security, our policy in the region has been aimed at strengthening the sovereignty and economic viability of new nation-states, enhancing regional cooperation, and avoiding the potential bottlenecks and conflicts that might arise from rising petroleum exports through the Turkish Straits.

Latin America

The United States benefits from strong energy relationships with Western Hemisphere countries. In 2004, three of four of our largest oil import suppliers were from the Hemisphere: Mexico (15.9 percent), Canada (15.8 percent), and Venezuela (12.9 percent). Canada is our number one supplier of natural gas while Trinidad and Tobago is our largest supplier of liquefied natural gas. The United States participates in regular dialogue with Mexico and Canada to integrate the North American energy market. We also support Mexico's Mesoamerican Energy Initiative, which aims to integrate Central American and Dominican Republic energy markets. We are working throughout the region to promote use of alternative and renewable sources of energy, building on Brazil's position as a world leader in the production of biofuels.

Strategic Petroleum Stocks

A second pillar of our international energy security policy is the multilateral cooperation we have forged through our membership in the International Energy Agency (IEA). Formed in the wake of the 1973 Arab oil


Paulo Whitaker/REUTERS

A man works at an ethanol distillery in the southern Brazilian state of Parana.

embargo, the IEA coordinates releases from emergency stockpiles for those events that shake global energy markets. Collectively, IEA members hold 1.4 billion barrels of strategic stocks, equal to some 115 days of imports. The U.S. Strategic Petroleum Reserve holds nearly 700 million barrels, or roughly half of total global strategic stocks. In 2005, the IEA's rapid release of stockpiles worldwide from its 26 members in the wake of the devastation of Hurricanes Katrina and Rita helped to stabilize the markets and kept those events from causing even more disruption. Collectively, IEA members made 60 million barrels of oil available to the market. This was only the second time in the IEA's history that stocks were released, but the action had an immediate calming effect on world markets. We are encouraging other major consuming countries, such as India, China, and member states of the Association of Southeast Asian Nations to hold strategic petroleum stocks, and support enhanced efforts to bring India and China into closer cooperation with the IEA on both short-term emergency response policies and broader energy security and technology policies.

"While we can be sure that the world will still have a great need for oil and gas, developing alternatives and renewable sources now is in everyone's long-term interest."

Dialogue With Producers

A third pillar of our international energy security policy is to maintain an active dialogue with major oil- and gas-producing countries. Our objectives are not only to exchange information on oil markets, but to encourage producers to maintain responsible production policies, to support a growing world economy, and to reduce oil market price volatility. We have pursued dialogues with a number of the major oil-producing states, particularly Middle Eastern producers, for a number of years, in some cases since the 1980s. These have included formal bilateral exchanges with some countries, and regular discussions among high-level officials and through our embassies in the region.

As evidence of the maturing relationship between producing and consuming countries, the IEA member states and Asia Pacific Economic Cooperation (APEC) countries are working with key Organization of Petroleum Exporting Countries producers to improve the efficiency and transparency of oil markets—to try to avoid the sort of market surprises that led to some of the shortages we see today. Since the 1990s, the United States has actively participated in the global producer-consumer energy dialogue, which has developed into the International Energy Forum (IEF). The IEF is an informal group consisting of about 50 countries and international organizations dedicated to promoting better understanding of international oil and energy market developments and policy issues among its members. The IEF secretariat, located in Riyadh, Saudi Arabia, is leading efforts on developing the Joint Oil Data Initiative (JODI), which is designed to improve transparency and information sharing in the global oil market.

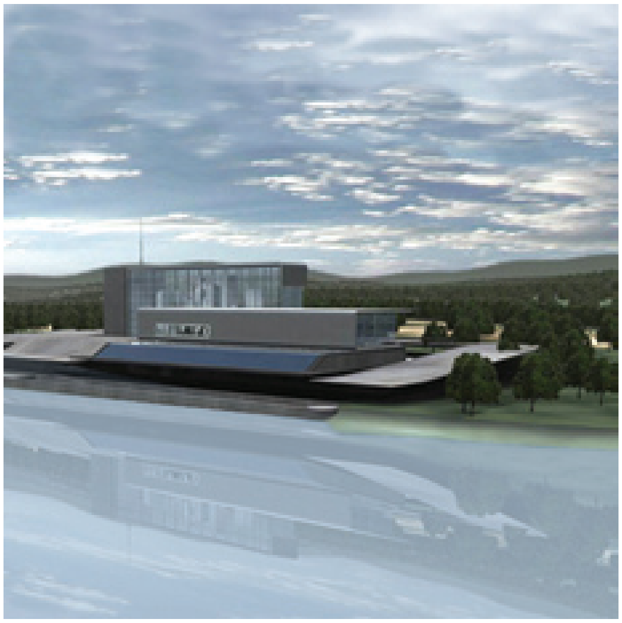
Energy Efficiency and Alternative Energy Sources

The oil crunch of the 1970s also encouraged more progress in the area of energy conservation and efficiency. Since 1970, the energy intensity of the U.S. economy—the amount of energy we consume per dollar of gross domestic product (GDP)—has fallen by almost 50 percent thanks to efforts at conservation. We support programs that provide for incentives for enhanced energy efficiency, conservation, and reductions in greenhouse gas emissions. In the United States, for example, Energy Star labels, which signal high efficiency in office buildings and appliances, were initially developed for domestic use, but they have proven so successful that they have been adopted in many countries.

Alternative Energy Sources

The United States is also engaged in multilateral efforts to obtain alternative energy sources. Several nations have already joined us in a multilateral partnership known as the Generation IV International Forum, which conducts research and development for the next generation of safer, more affordable, and more proliferation-resistant nuclear energy systems. We are working with several countries on FutureGen—an initiative to build the world's first integrated carbon-sequestration and hydrogen-production research power plant. The $1-billion-dollar project is intended to create the world's first zero-emissions fossil fuel plant.

Most recently, the United States put forth a bold new vision of the future of nuclear power known as the Global Nuclear Energy Partnership (GNEP). Through GNEP, the United States will work with other nations possessing advanced nuclear technologies to develop new



An artist's rendering of a FutureGen coal plant.

proliferation-resistant nuclear fuel recycling technologies in order to increase U.S. and global energy security; provide for expanded use of economical, carbon-free nuclear energy; minimize nuclear waste; and curtail proliferation concerns. Additionally, these partner nations will develop a fuel services program to provide nuclear fuel to developing nations, allowing them to enjoy the benefits of abundant sources of clean, safe nuclear energy in a cost- effective manner in exchange for their commitment to forgo enrichment and reprocessing activities, thus alleviating proliferation concerns.

The United States has initiated, or served as a founding member of, several international technology partnerships designed to share data and best practices among nations while reducing the time and expense needed to achieve technological breakthroughs. For example, the International Partnership for a Hydrogen Economy was formed to advance the global transition to the hydrogen economy, with the goal of making fuel cell vehicles commercially available by 2020. The Methane-to-Markets Partnership works closely with the private sector to develop methods to recapture waste methane escaping from landfills, leaking from poorly maintained oil and gas systems, and vented from underground coal mines. In order to obtain improved energy security, reduce pollution, and address the long-term challenge of climate change, the United States, along with China, India, Japan, Australia, and the Republic of Korea, recently launched the Asia-Pacific Partnership for Clean Development and Climate. The partnership will focus on voluntary practical measures taken by the six countries to create new investment opportunities, build local capacity, and remove barriers to the introduction of clean, more efficient technologies.

Earlier in 2006, President Bush announced a major new initiative, the Advanced Energy Initiative, to invest in new technologies that we believe can change the way we power our homes, our businesses, and our automobiles. By developing new energy technologies, such as biofuels, hydrogen, and solar, we should be able to take pressure off markets, enhance the sustainability of precious natural resources, and keep energy prices affordable. The president's strong support for research into the potential of cellulosic ethanol as a fuel source and battery technology for plug-in hybrid vehicles is particularly important to reduce our dependence on petroleum-based transport fuels. And while we can be sure that the world will still have a great need for oil and gas, developing alternatives and renewable sources now is in everyone's long-term interest. Many of these fuels are cleaner forms of energy that complement our environmental goals as well by emitting fewer pollutants into the air.

Working in Global Partnership

As President Bush and Secretary of State Condoleezza Rice have noted, we remain concerned with the potential economic risks posed to the United States by reliance on imported oil and by instability in the Middle East, where much of the world's oil is produced. At the same time, oil is a global commodity, and a disruption in supply anywhere in the world will have an immediate impact on all oil-importing countries, no matter where their oil comes from.

Energy security is a leading priority of the U.S. government. However, energy security can only be achieved by working in global partnership with other countries. Our bilateral and multilateral relationships are the means through which the United States will achieve energy security. The United States has a national interest in working with other countries to ensure that reliable, affordable, and environmentally sound energy is available to power U.S. and world prosperity. ■

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INTERNET RESOURCES

Selected sources of information on clean energy

U.S. GOVERNMENT

Energy Star
http://www.energystar.gov/
Interagency program helping businesses and individuals to protect the environment and save energy through energy efficiency.

U.S. Department of Energy (DOE)

Idaho National Laboratory
http://www.inl.gov/
Science-based, applied engineering national laboratory dedicated to meeting America's environmental, energy, nuclear technology, and national security needs.

Lawrence Berkeley National Laboratory
http://www.lbl.gov/
DOE-supported laboratory that conducts research across many disciplines, with key eforts in fundamental studies of the universe, quantitative biology, nanoscience, new energy systems and environmental solutions, and integrated computing.

National Energy Technology Laboratory
http://www.netl.doe.gov/about/index.html
Part of the DOE national laboratory system that implements research and development programs to resolve the environmental, supply, and reliability constraints of producing and using fossil resources.

National Renewable Energy Laboratory
http://www.nrel.gov/
DOE-supported laboratory that develops renewable energy and energy-efficiency technologies and practices and advances related science and engineering.

Office of Energy Efficiency and Renewable Energy
http://www.eere.energy.gov/
DOE office that advances the commercialization and deployment of renewable energy and energy-efficiency technologies.

U.S. Department of State

Bureau of Economic and Business Affairs
Office of International Energy and Commodity Policy
http://www.state.gov/e/eb/c9982.htm
State Department bureau that coordinates the department's liaison with major energy-producing countries and organizations.

Bureau of Oceans and International Environmental and Scientific Affairs
http://www.state.gov/g/oes/
State Department bureau that coordinates policies related to science, the environment, and the world's oceans.

ACADEMIC, PRIVATE, AND NONPROFIT ORGANIZATIONS

Alliance to Save Energy
http://www.ase.org/
Coalition of business, government, environmental, and consumer leaders that supports energy efficiency.

American Council on Renewable Energy
http://www.acore.org/
Nongovernmental group that promotes renewable energy options for the production of electricity, hydrogen, and fuels, as well as for end uses.

Alliance for Mindanao Off-Grid Renewable Energy
http://www.amore.org.ph/
U.S. Agency for International Development partnership with private groups and nongovernmental organizations designed to provide electricity from renewable sources to villages on the southern Philippines islands.

Asia-Pacific Partnership on Clean Development and Climate
http://www.asiapacificpartnership.org/default.htm
Multilateral effort to accelerate the development and deployment of clean-energy technologies.

Clean Edge
http://www.cleanedge.com/
Research and publishing firm specializing in clean-energy markets.

Clean Energy Group
http://www.cleangroup.org/
Nonprofit group that promotes greater use of clean energy technologies through innovation in finance, technology, and policy.

Energy Voyager
http://www.energyvoyager.com
Consulting firm that supports energy innovators and entrepreneurs.

Environmental and Energy Study Institute
http://www.eesi.org/index.html
Nonprofit provider of information services and public policy initiatives on environmentally sustainable societies.

Global Village Energy Partnership
http://www.gvep.org/
Partnership of public and private groups that aims at ensuring access to modern energy services for the poor.

Massachusetts Institute of Technology (MIT)
Energy Research Council
http://web.mit.edu/erc/index.html
Program that explores how to best match MIT expertise with global needs and produce a plan for tackling the world energy crisis through science, engineering, and education.

Partnership for Clean Fuels and Vehicles
http://www.unep.org/PCFV/Main/Main.htm
International initiative to reduce vehicular air pollution in developing countries through the promotion of clean fuels and vehicles.

Pennsylvania Department of Environmental Protection
http://www.depweb.state.pa.us/dep/site/default.asp
Agency of one of the 50 U.S. states that is responsible for administering the state's environmental laws and regulations.

Renewable Energy Access
http://www.renewableenergyaccess.com/rea/home
An Internet source for information on renewable energy.

Rice University
Baker Institute Energy Forum
http://www.rice.edu/energy/index.html
Program dedicated to educating policy makers and the public about important energy trends.

Rocky Mountain Institute
http://www.rmi.org/
Nongovernmental organization that promotes market-based, integrative solutions aimed at fostering efficient and restorative use of resources.

Stanford University
Global Climate and Energy Project
http://gcep.stanford.edu/
Long-term research effort on technologies that will permit the development of global energy systems with significantly lower greenhouse gas emissions.

UN Commission on Sustainable Development
http://www.un.org/esa/sustdev/csd/policy.htm
Organization responsible for monitoring implementation of United Nations' policies on environment and sustainable development.

World Alliance for Decentralized Energy
http://www.localpower.org/
Nongovernmental organization that promotes worldwide deployment of on-site renewable energy, cogeneration, and energy recycling systems.

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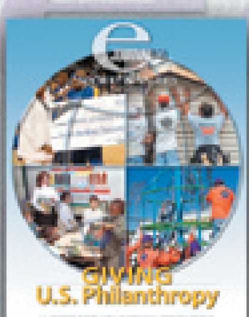

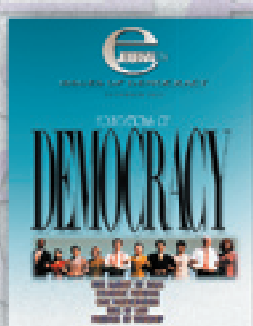

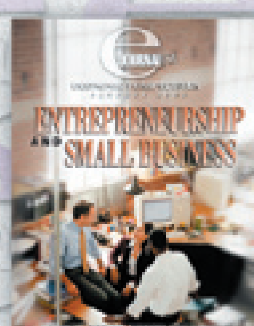

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