❑ RENEWABLE ENERGY AND NEW TECHNOLOGIES

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Energy research has made huge strides over the past three decades, both in improving the efficient use of traditional fuels and in developing and deploying next-generation technologies that could eventually transform the energy sector, says Garman. Meeting long-term needs for clean energy in the United States and the world will require leapfrogging to new technologies while concurrently continuing investments in energy efficiency, renewable alternatives to fossil fuels, and cleaner non-renewable alternatives, he says.

ENERGY CHALLENGES

Energy is the lifeblood of modern nations and is a mainstay of high standards of living, sophisticated economies, and national security. While greater efficiency of existing energy sources is essential in the short term, the United States, like other nations, must look toward "next generation" technologies, such as hydrogen and nanotechnology, to meet the increasing challenges of providing clean, abundant, reliable, and affordable energy to all people.

The United States' strategic approach to the energy sector is contained in President Bush's National Energy Policy (NEP), published in May 2001. The NEP draws attention to the fact that a serious imbalance between U.S. domestic energy supply and domestic energy demand underlies our nation's energy challenge. It shows that the United States consumes much more energy than it produces and that our dependence on imported energy grows worse each year. The NEP also provides guidance on what we can do about it.

Several features of our current energy economy:

• We enjoy a diversity of primary energy inputs such as fossil energy (oil, coal, and natural gas), nuclear energy, and renewable energy.
• But, we are heavily dependent on oil, coal, and natural gas.
• The transportation sector is almost entirely dependent (97 percent) on oil, a majority of which is imported.
• In all sectors of energy use, a large amount of energy is rejected or wasted, with transportation being the least efficient of the three main sectors (residential/commercial, industry, and transportation) of our economy.

Promoting efficiency in the use of oil and finding new domestic sources of oil are both important short-term undertakings. But over the long term, a petroleum-free option is eventually required.

The U.S. energy challenge is further complicated by another important factor — the pollutants and carbon dioxide emissions resulting from our use of energy. Although we have made good progress in reducing pollutant emissions from our cars and trucks as well as from factories, homes, and other stationary sources, ultimately new approaches to energy will be required to achieve further emission reductions.

The United States Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) leads the federal government's research, development, and deployment (RD&D) efforts in biomass, geothermal, solar, wind, and other renewable and energy-efficiency technologies to provide reliable, affordable, and environmentally sound energy supplies for America's future. As a result of investing billions of dollars in research, demonstration, tax incentives, and other policy measures over the past three decades, tremendous progress has been made in increasing the efficiency of energy use in our economy and in bringing renewable energy technologies to the marketplace. While our investments — and those of our industry partners — are beginning to pay off, with dramatic and ongoing improvements in the cost and efficiency of these technologies, much more remains to be accomplished to meet our current energy challenges.

THE PROMISE OF HYDROGEN

The development of next-generation energy technology such as hydrogen could greatly reduce the United States' reliance on energy imports, particularly in the transportation sector. Since hydrogen is not an energy source but rather an energy carrier, it can be produced from all primary energy sources including natural gas, coal, nuclear energy, and renewable energy. Hydrogen can

fuel ultra-clean internal combustion engines, which would reduce auto emissions by more than 99 percent. And when hydrogen is used to power fuel-cell vehicles, it will do so with more than twice the efficiency of today's gasoline engines and with none of the harmful air emissions. In fact, fuel cells' only byproducts are pure water and some waste (excess) heat. Hydrogen fuel cells could also be used in stationary applications, providing electricity for homes, offices, shopping centers, and other buildings.

Since the release of the NEP, President Bush and Energy Secretary Spencer Abraham have unveiled several initiatives related to hydrogen. Most notable are the FreedomCAR partnership announced in January 2002; President Bush's Hydrogen Fuel Initiative, announced during the State of the Union address in January 2003; and "FutureGEN," a zero-emission coal-fired electricity and hydrogen power plant project that includes sequestration — capture and storage — of greenhouse gas emissions, announced in February 2003. In his 2003 State of the Union speech, President Bush announced that "With a new national commitment, our scientists and engineers will overcome obstacles by taking these cars from laboratory to showroom, so that the first car driven by a child born today could be powered by hydrogen and pollution-free." All of these initiatives are contributing to a national approach for moving toward a hydrogen economy through development of the necessary advanced technologies for hydrogen production, delivery, storage, conversion, and applications.

The federal government's role is to accelerate hydrogen and fuel cell development to enable industry to make a commercialization decision by 2015. But the manufacturing and marketing of fuel-cell or other advanced vehicles will be industry's responsibility. Achieving this vision will require a combination of technological breakthroughs, market acceptance, and large investments in a national hydrogen energy infrastructure. Success will not happen overnight, or even in years, but rather over decades, and it will require a steady process that phases in hydrogen as the technologies and markets are becoming ready.

OTHER NEXT-GENERATION TECHNOLOGIES

In addition to resolving critical energy needs for transportation, there is a need to increase energy efficiency in other sectors, such as buildings. With an expanding population and increased amenities that require more electricity, building-related energy consumption in the United States is growing. New technologies will be needed for a new generation of buildings that will be efficient, comfortable, and simpler to operate and maintain. For example, solid-state lighting that uses semiconductor light-emitting diodes (LEDs) is a revolutionary technological innovation that promises to change the way we light our homes and businesses. In the United States, lighting consumes nearly 30 percent of all electricity produced for buildings. While modern fluorescent bulbs with electronic ballasts are much more efficient than incandescent bulbs, they remain glass nodules filled with gas, not unlike the vacuum tubes of the last generation of electronics. The LED is to fluorescent lamps what transistors were to vacuum tubes, or what the automobile was to horse-powered transportation.

In the long term, U.S. research is focused on "zero-energy buildings" that on average actually could produce more energy than they consume by combining highly efficient design with fuel-cell, solar, geothermal, and other distributed energy and cogeneration technologies. Already, solar cells which convert sunlight directly to electricity, known as photovoltaics (PV), are helping to supplement buildings' energy needs through thin film PV panels located on roofs, as well as providing electrical power to distributed power applications not served by the electric grid. Distributed energy resources (DE) are a variety of small, modular power-generating technologies that can be combined with energy management and storage systems and used to improve the operation of the electricity delivery system, whether or not those technologies are connected to an electricity grid.

DOE is also active in nanotechnology research and development. Nanomaterials — typically on the scale of a billionth of a meter or 1,000 times thinner than a human hair — offer different chemical and physical properties than the same materials in bulk form and have the potential to foster new technologies. According to Secretary Abraham, "This new science of very small things can revolutionize the way we produce, use, and deliver energy." Certain nanomaterials show promise for use in making more efficient solar cells and the next-generation catalysts and membranes that will be used in hydrogen-powered fuel cells. Because of their nanoscale size and excellent conductivity, carbon nanotubes, essentially sheets of graphite rolled into extremely narrow tubes a few nanometers in diameter, are being studied as the possible building blocks of future electronic devices. Woven into a

cable, carbon nanotubes could provide electricity transmission lines with substantially improved performance over today's power lines.

These are just a few examples of how new technologies offer the promise of a radically different energy future.

CONTINUING EFFORTS IN ENERGY EFFICIENCY AND RENEWABLE ENERGY

As important as hydrogen and other "leapfrog" innovations may be in the long run, EERE is continuing to make investments in "workhorse" energy efficiency and renewable energy improvements that will have an impact in the more immediate future. Under the FreedomCAR and Vehicle Technologies Program, we are funding hybrid (gasoline-electric and diesel-electric) technology and lightweight material technologies, in addition to hydrogen fuel-cell technologies. We believe that many of these technologies will deliver fuel savings both prior to and after the introduction of fuel-cell vehicles, since lightweight materials and hybrid technologies are expected to be incorporated into fuel-cell vehicle designs. In addition, we are funding research and development to continue progress in improving energy efficiency in manufacturing and other industries, in appliances, in buildings, and in electricity power transmission and distribution.

EERE is also actively supporting research and development to improve the performance and competitiveness of a variety of renewable energy supply technologies such as wind, solar, geothermal, and biomass. For example, wind energy is one of the most widely used and fastest-growing renewable energies in the world. Since 2000, installed wind turbine electric generation capacity in the United States has more than doubled. With support from DOE-sponsored research, the cost of electricity generation from wind has been reduced by a factor of 20 since 1982, to four cents or less per kilowatt-hour in areas with excellent wind resources. While these resources are being exploited by industry, the department's research and development (R&D) programs have turned to focus on new technology that will make even more widely available lower-speed wind resources viable for development. "Low wind speed" technology will expand available land (and potentially, off-shore) areas for wind development by a factor of 20.

MECHANISMS TO ASSIST TECHNOLOGY RD&D

The Department of Energy uses a variety of investment, policy, and other mechanisms to assist technology RD&D including direct R&D investments, partnerships with the private sector, basic scientific research, investment and production tax credits, loan guarantees, the "market pull" of the government's purchasing power, and consumer education and assistance programs. The administration continues to support comprehensive legislation that would promote energy efficiency and renewable energy, including production tax credits for renewable energy, a renewable fuels standard to support biomass-derived ethanol and biodiesel, and a variety of other energy efficiency provisions. In addition to the federal government, state governments have a number of policies that promote the use of renewable and other technologies, such as net metering, which allows customers to generate their own renewable power and sell any excess back to utilities. Increasingly the U.S. public has the ability to choose to receive electricity through "green power" programs that utilize a variety of renewable energy sources including wind, solar, biomass, and geothermal. There are already 1000 megawatts of green power that have been installed (or planned) nationwide because of customer demand in green power markets.

U.S. WORKING WITH OTHER NATIONS

Because much of the world faces the same kinds of energy challenges as the United States, technology developments by U.S. companies will benefit other nations as well. Furthermore, helping developing nations to use energy more efficiently and develop alternative energy sources may enable them to leapfrog directly to advanced energy technologies. The Department of Energy has numerous bilateral and multilateral agreements to promote energy technologies with other countries, including a recently formed International Partnership for the Hydrogen Economy (IPHE) to promote the research, development, and demonstration of hydrogen technologies and accelerate the conversion of the world economy to one that employs environmentally clean hydrogen technologies. The Terms of Reference document, formally creating the IPHE, was signed by Secretary Abraham and ministers representing 14 other nations and the European Union in November 2003. The IPHE will provide a mechanism to organize, evaluate, and coordinate multinational research, development, and deployment programs that advance the transition to a global hydrogen economy.

DOE is also part of an international climate change initiative known as the Carbon Sequestration Leadership Forum (CSLF) whose purpose is to facilitate the development of improved cost-effective technologies that capture and store carbon emissions. The charter for the CSLF was signed in June 2003 and currently has 16 coal-producing and -consuming members. Carbon sequestration is a priority for the United States because fossil fuels (consumption of which produces carbon dioxide) will continue to be the world's most reliable and lowest-cost energy resources for the immediate future.

Other initiatives include the Generation IV International Forum, where the department is working with a group of international government entities to facilitate bilateral and multilateral cooperation on development of new nuclear energy systems. The United States has also rejoined the International Thermonuclear Experimental Reactor (ITER), a project to develop nuclear fusion as a future energy source. Although the technical hurdles for nuclear fusion are complex, its promise is considered too great to ignore.

CONCLUSION

The United States and other nations face a number of challenges to providing clean, abundant, reliable, and affordable sources of energy to their citizens. U.S. policy is focusing on leapfrogging to next-generation technologies, such as hydrogen, while concurrently working on increases in efficiency, on alternatives to fossil fuels, and on cleaner non-renewable alternatives, all of which are likely to be an important part of the future energy landscape. ❑