A WORD FROM THE OFFICE OF NATURAL GAS AND PETROLEUM TECHNOLOGY

IN THE PAST THREE DECADES, the petroleum business has transformed itself into a high-technology industry. Dramatic advances in technology for exploration, drilling and completion, production, and site restoration have enabled the industry to keep up with the ever-increasing demand for reliable supplies of oil and natural gas at reasonable prices. The productivity gains and cost reductions attributable to these advances have been widely described and broadly recognized. But public awareness of the significant and impressive environmental benefits from new exploration and production (E&P) technology advances remains limited. • THE U.S. DEPARTMENT OF ENERGY is responsible for achieving national objectives in the fields of energy and the environment. We believe it is important to tell this remarkable story of environmental progress in E&P technology. Greater awareness of the industry's achievements in environmental protection will provide the context for effective policy, and for informed decision making by both the private and public sectors. • LOOKING FORWARD, the domestic oil and gas industry will be challenged to continue extending the frontiers of technology. Ongoing advances in E&P productivity are essential if producers are to keep pace with steadily growing demand for oil and gas, both in the United States and worldwide. Continuing innovation will also be needed to sustain the industry's leadership in the intensely competitive international arena, and to retain high-paying oil and gas industry jobs at home. Progressively cleaner, less intrusive, and more efficient technology will be instrumental in enhancing environmental protection in the future. • OUR NATION has come to expect the benefits of fossil-based fuels and products and a clean environment. The oil and gas industry has consistently responded to provide both. The Department of Energy looks forward to increased dialogue with the oil and gas industry and other stakeholders. With commitment to a shared vision, with collaboration, and with continued private and public investments, the oil and gas industry can continue to deliver essential energy resources and protect the environment, for ourselves and for the generations to come.

SITE RESTORATION | TRANSPORTATION | REFINING AND PRODUCTION | PRODUCTS | POWER GENERATION

The U.S. oil and gas industry employs 1.4 million people and generates about 4 percent of U.S. economic activity. It is larger than the domestic auto industry and larger than education and social services, the computer industry, and the steel industry combined. The exploration and production sector alone employed nearly 326,000 people in 1998.

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Executive Summary

Oil and Natural Gas Are Critical to the U.S. Economy

Oil and natural gas account for virtually all transportation fuel in the United States and a majority of our total energy use, and provide the raw materials for countless products used in our daily lives. Americans have come to take these resources and products largely for granted and expect them to be available and affordable.

For over a century, the oil and gas industry has successfully met rising demand for these valuable resources.

Continuous innovation has characterized the oil and gas industry throughout its history. In recent decades, new technologies have been key to finding and extracting recoverable oil and gas resources—located in deeper and more remote locations, in more challenging geologic formations, in difficult terrain, in smaller pockets, under sensitive wetlands and tundra, and far out at sea. As the world's most mature oil and gas province—and home of some of the world's most rigorous environmental standards—the United States has been the site of much of the industry's innovation in exploration and production (E&P) technology.

American ingenuity, know-how, and entrepreneurial spirit have created the necessary technology to maintain reliable oil and gas supplies in a volatile marketplace.

Technology innovation has enabled the domestic industry to remain viable in an energy business where highly competitive global markets determine prices. The industry has developed more efficient E&P technology to enable continued exploration, development, and production through the boom and bust cycles that are characteristic of world oil markets.

Nowhere have the dual requirements of producing more challenging resources and protecting the environment been as pressing as in the United States.

Hand-in-hand with overcoming tough geologic and geographic conditions, the industry has also developed new technology and management techniques for enhanced protection of our environment.

While increasing productivity, technology innovation has also yielded environmental benefits.

Today's exploration technology, for example, is boosting industry success rates in pinpointing new resources. The results: fewer dry holes, reduced waste volumes, and less environmental disruption. Across the E&P spectrum, new technology is delivering:

- *More efficient recovery of oil and gas resources.* Continuing improvements in recovery efficiency per well translate into fewer wells (and less impact from drilling operations) to achieve the same level of reserves.
- *Smaller footprints.* Smaller, lighter rigs and advances in directional and extended-reach drilling shrink the footprint of oil and gas operations and reduce surface disturbance.
- *Cleaner, safer operations.* Advanced, more energy-efficient drilling and production methods cut emissions of air pollutants and greenhouse gases, practically eliminate spills from offshore platforms, and translate into enhanced worker safety, lower risk of blowouts, and better protection of groundwater resources.

Environmental Protection is Good Business

THE U.S. OIL AND GAS INDUSTRY has integrated an environmental ethic into its business culture and operations. The industry has come to recognize that high environmental standards and responsible development are good business, and it is demonstrating its commitment to protecting the environment in research and technology investments, policies and practices, and participation in a host of voluntary environmental protection programs. Industry's use of smarter, more efficient technology complements these trends.

Advanced E&P technology provides environmental benefits beyond the oil and gas industry.

Innovations pioneered by the oil and gas industry are now being used in a wide range of applications. Geologic and geophysical technology are providing information on the fundamental characteristics of the earth's crust, enabling better prediction and evaluation of earthquakes and other geologic hazards. Reservoir simulation and performance-monitoring technology are being used to predict groundwater flow patterns. And the same principles used to increase the recovery of oil — such as thermal and microbial processes — are now applied to clean up chemical spills.

Continued technology progress will be essential in meeting the challenges of the 21st century.

Further increases in productivity will be essential to sustain the viability of the U.S. petroleum industry in the face of a sometimes volatile world oil market. Industry and government leadership and American ingenuity will be necessary to preserve our Nation's oil and gas production capacity and energy security. In the longer term, technology innovation will be critical to ensure optimal recovery of America's oil and gas resources, while respecting the environment and other public values. Technology innovation will be key to overcoming the constraints of an increasingly challenging resource base, domestically and around the world.

Industry and government both have roles in advancing E&P technology progress and environmental performance.

Environmental quality will be a continuing issue for the oil and gas industry. America's oil and gas industry must find the means, including new technology, to address future environmental challenges, such as global climate change. Industry must continue to demonstrate its commitment to responsible development. Government must provide a rational regulatory framework and reasonable access to resources. Open communication is also critical to meeting these objectives. Continued investment, both private and public, will be required to advance E&P science and technology.

America's legacy of technology progress and improved environmental management in E&P provides a solid foundation for meeting the challenges of the future.

INNOVATION IN OIL AND GAS E&P TECHNOLOGY:
MAKING A DIFFERENCE TO THE ENVIRONMENT

Right Where We Live and Around the Globe

FROM COAST TO COAST, INNOVATIVE E&P approaches are making a difference to the environment. With advanced technologies, the oil and gas industry can pinpoint resources more accurately, extract them more efficiently and with less surface disturbance, minimize associated wastes, and, ultimately, restore sites to original or better condition. Most of these advances have been pioneered in the United States, but many are now also providing benefits around the globe.

Increasingly, in our own backyards and in all corners of the earth, innovation is the key to producing oil and gas while protecting neighborhoods and natural habitats. Here are just a few examples of the contributions being made by new technology.

WEST COAST
California

- ARCO Long Beach, Inc.'s production operations in Long Beach Harbor represent a model approach to operating in sensitive urban environments. To shield the harbor's operations from the public, drilling rigs are disguised as high-rise buildings, and other above-ground facilities have been masked with palm trees, concrete sculptures, waterfalls, and colorful night-lighting. Advanced horizontal drilling and hydraulic fracturing technology, combined with the largest waterflood in California's history, have increased production by approximately 30 percent in recent years.
- In the southern California town of La Habra, the area's rolling hills, once the site of oil production from the West Coyote field, are now covered with premium homes, thanks to painstaking site restoration upon the field's closure.
- Thermal enhanced oil recovery technology is increasing production rates and ultimate recovery from the mature, "heavy" oil fields of Kern County, California, and surrounding areas. For example, decades-old steam floods are facilitating production at some of the Nation's largest, most mature fields, including Midway-Sunset, South Belridge, and Kern River.

■ Major areas of oil and gas potential

NORTHERN PLAINS
Montana, North Dakota, South Dakota

- Advanced horizontal drilling and measurement-while-drilling technology are enabling recovery of previously untapped resources in the Williston Basin's Red River B Formation, spread across Montana and the Dakotas. In 1994, horizontal drilling technology facilitated the discovery of the Cedar Hills play, the Nation's largest onshore discovery in the last 25 years.

GULF OF MEXICO AND GULF COAST
Texas, Louisiana, Mississippi, Alabama, Florida

- New subsalt imaging technologies, aided by today's super-powered computers and advanced mathematical modeling concepts, are enabling operators to get a clearer picture of the Gulf's hydrocarbon-rich subsalt play, facilitating exploration success and greater resource recovery.

- Advanced offshore platforms—tension leg platforms; mini-TLPs; spars; and floating production, storage, and offloading systems—and subsea completions are equipping offshore operators to explore and produce in deeper, more remote, and harsher environments. These advances enable increased access to deepwater resources, while minimizing disruptions to ocean ecosystems.
- State-operated artificial reef programs turn decommissioned offshore platforms into permanent reef structures, creating complex and vibrant subsea "living communities" and also enhancing commercial and recreational fishing opportunities.
- Synthetic drilling fluids are fast becoming the drilling fluid of choice for many complex deepwater drilling operations. Combining the advanced operational properties of oil-based muds with the environmental benefits of water-based drilling fluids, synthetic fluids enable operators to drill faster and cheaper, with less overall environmental impacts.

ROCKY MOUNTAINS

Wyoming, Colorado, New Mexico

- In the gas-rich San Juan Basin, advanced coalbed methane production and completion technologies—such as nitrogen injection and CO_2 flooding—are unlocking clean-burning methane from coal seams, substantially increasing our domestic gas supply.
- Smarter operations in the Rockies enable successful exploration and production while protecting an environment marked by rugged mountains, sensitive Federal lands, and fragile habitats. For example, in Wyoming's Bridger-Teton National Forest, drilling operations were conducted using a helicopter to transport the drilling rig and other heavy equipment, minimizing environmental impacts.

APPALACHIA

Pennsylvania and Kentucky

- Field trials in central Pennsylvania and the Devonian Shales of Kentucky indicate that innovative CO_2-sand fracturing technology can significantly increase gas production in certain types of wells and reservoirs, while reducing waste volumes and formation damage.
- In Pennsylvania, "roadspreading" brine produced from oil and gas wells has proven to be an effective dust suppressor and road stabilizer on unpaved secondary roads. This beneficial use of an oilfield waste reduces the volume of wastes that would otherwise need to be disposed of by oil and gas operators.

MID-CONTINENT

Nebraska, Kansas, Oklahoma

- Visitors to Oklahoma City's Will Rogers World Airport are greeted with the sight of pumpjacks and other production equipment and facilities—the airport is located in the heart of an active oil field.
- Funded exclusively through voluntary contributions by Oklahoma's oil and gas producers and royalty owners, the Oklahoma Energy Resources Board (OERB) restores orphaned and abandoned well sites around the State. By removing abandoned oilfield tanks and other equipment and remediating saltwater erosion and oil-stained soil, OERB is returning land to productive use, at no cost to landowners.

TEXAS

- Advances in horizontal and multilateral drilling have been critical to increasing production in the mature, highly fractured Austin Chalk play in southeast Texas. In the Clay NE field, for example, horizontal drilling has increased gas production fourfold since 1991. The Chalk has been the site of 90 percent of U.S. horizontal land rigs since the late 1980s.
- Since the early 1970s, the Permian Basin region of west Texas and southeast New Mexico has been home to innovative miscible CO_2-injection enhanced oil recovery projects. The largest and oldest of these projects, the SACROC Unit in Scurry, Texas, is a fieldwide project over nearly 50,000 acres that began over 25 years ago.

ALASKA

- Ice roads and ice pads have significantly reduced the impacts of exploratory drilling operations on the North Slope, protecting the area's fragile tundra and ecosystem.
- Extended-reach, horizontal, multilateral, and "designer" directional drilling technology has enabled North Slope operators to tap more resources, while minimizing drilling footprints and avoiding sensitive habitats.
- In the past 30 years, production footprints have shrunk dramatically. Production pads have been reduced by up to 80 percent, and wellhead surface spacing has been reduced by over 75 percent. If built today, the Prudhoe Bay oilfield's footprint would be 64 percent smaller.