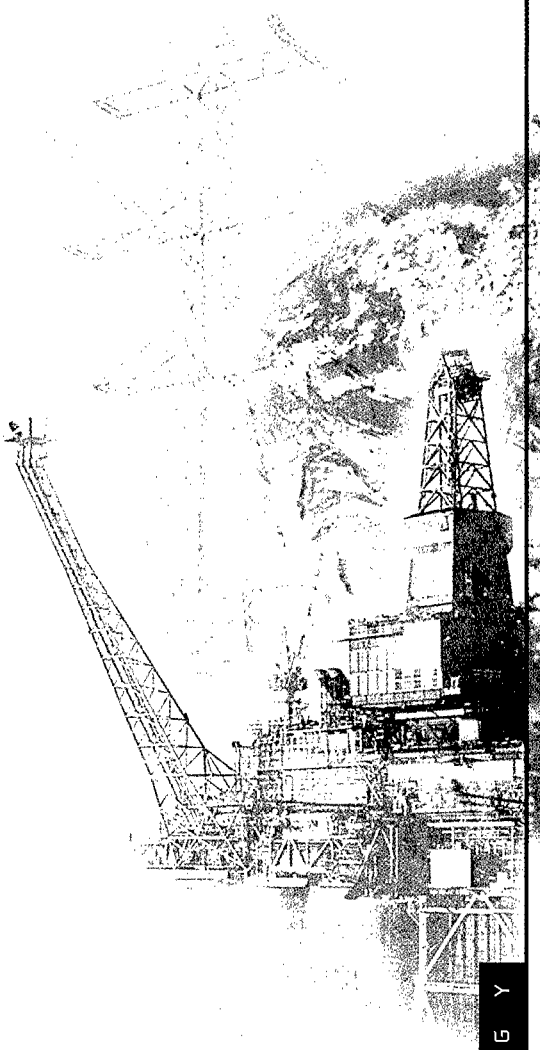
21st CENTURY TECHNOLOGIES



GLOBAL ENERGY

FOSSIL FUELS

COAL & POWER SYSTEMS

NATURAL GAS & OIL

ENERGY SECURITY

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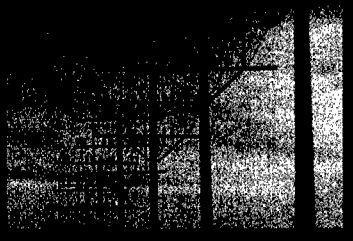
FOSSIL FUELS—FUTURE FUELS

Electric power. transportation. and industrial processes: these major components of a prosperous economy all depend on fossil fuels. More than 85% of our energy is supplied by coal. petroleum. and natural gas. While we will diversify our energy sources over time to take advantage of renewable resources. fossil fuels will remain our dominant sources of affordable energy well into the 21st century. Moreover. the rapid expansion of global economies is increasing the world's consumption of these fuels.

The programs described here address two major challenges confronting our continued use of fossil fuels at the dawn of a new century:

ENVIRONMENTAL PROTECTION

As the world relies on greater quantities of fossil fuels. we have increasing concerns about greenhouse gases. which are largely produced by energy use. Building on the success of earlier technologies that have brought solutions to other air emissions problems. the Department of Energy's Fossil Energy pro grams are developing technologies that minimize the carbon dioxide released by fossil fuels. particularly by coal. At the same time. advanced concepts are being developed to reduce smog- and acid-rain-causing emissions to almost negligible levels. Using natural gas can also help meet many of our environ mental and energy needs. but sustaining confidence that supplies will remain abundant and affordable will require new technologies for producing and processing this clean-burning fossil fuel.



ENERGY SECURITY

We continue to confront the daunting challenge of declining domestic oil pro duction. Continued diligence in maintaining a viable Strategic Petroleum Reserve can give us the security of an immediate response should our oil supplies be interrupted. Over the longer term. new technologies. which have already increased the flow of oil from many of our domestic fields. could help reverse the decline of production from known fields and perhaps lead to exciting new discoveries.

Our Nation's progress will depend on how we meet these challenges. Innovation. creativity. and a commitment to preparedness have served us well in the past. They are proven routes. And if we continue to follow them. fossil fuels will be for us not fuels of the past but fuels of the future.

FOSSIL FUELS — THE DOMINANT ENERGY SOURCE FOR THE FORESEEABLE FUTURE

U.S. energy use is expected to increase by 27% between now and the year 2020, while worldwide the increase in energy demand is projected to be as high as 60% in the same time frame. More than 85% of U.S. energy and nearly 90% of the world's energy is currently supplied by fossil fuels.

Fossil fuels — coal, oil, and natural gas — built America's historic economic strength. Today, coal supplies more than 55% of our electricity, oil more than 97% of our transportation needs, and natural gas 24% of the primary energy used in the United States. Even taking into account increased use of renewable fuels and vastly improved powerplant efficiencies, 90% of our national energy needs will still be met by fossil fuels in 2020. If we can successfully develop and deploy advanced technologies that boost efficiency and environmental performance, the United States can continue to depend upon its rich resources of fossil fuels.

KEEPING ENERGY RELIABLE AND AFFORDABLE

How can our Nation ensure the continuing secure, affordable supplies of fossil fuels that are so critical to all aspects of our economy? Advanced technologies under development by government and industry partners in DOE's Fossil Energy program are key.

In DOE's R&D portfolio, for example, new systems are being developed to further improve the environmental performance of coal- and natural-gas-fueled powerplants, while keeping electricity costs down. To produce more of our domestic oil and natural gas reserves, progress is being made in such technologies as imaging, drilling, and well stimulation. Advanced processing technologies are now leading to flexible production of an array of clean, affordable fuel forms to meet the changing needs of users. And concurrently with the Fossil Energy R&D program, we continue to maintain an important first-line defense for national energy security: the Strategic Petroleum Reserve, which can be drawn on in the event of oil import disruptions.

The benefits of these programs will also extend beyond our national boundaries. Worldwide, other nations are even more dependent than the United States upon fossil fuels. Nearly 90% of the world's energy comes from fossil fuels. In coming years, the world's use of these fuels will soar, based on two phenomena: growth in world population, 98% of it in developing nations, and a dramatic growth in global economic expectations. The increase in electricity demand is expected to be particularly strong, doubling worldwide by 2015. Given the vast resources of coal that exist in both the industrialized and developing areas of the world, coal-fueled plants are projected to supply 36% of global electric power in this time frame.

MEETING THE GREATEST NEW CHALLENGE

Rapid growth in global energy use will exacerbate the greatest environmental challenge faced by the United States and other countries: the buildup of greenhouse gases.

When the United States joined the world community in Kyoto, Japan, in December 1997 to discuss a proposed treaty to reduce the output of greenhouse gases, it established its position that greenhouse gases must be reduced in the immediate future. To meet the target set by the Kyoto Protocol, the United States must reduce greenhouse gas emissions 7% below the 1990 rate by roughly 2010. Electric power systems contribute about one-third of the carbon dioxide (CO_2) emitted by the United States and are therefore critical to any climate-change initiative.

The Department of Energy's Fossil Energy Program, working in partnership with industry, is pursuing two complementary approaches to reducing CO_2 emissions by the electric power sector. First, it is developing new natural-gas- and coal-fired technologies that are more efficient than current electric power generating systems. More efficient powerplants require proportionately less fuel to generate electricity, and less fuel means fewer CO_2 emissions.

Second, the Office of Fossil Energy is sponsoring the development of innovative low-cost and environmentally friendly technologies to remove CO_2 from the fuel cycle and sequester it in ways that prevent its release for geologically significant time periods. It is carrying out research on novel approaches to sequestration, such as systems which mimic biological processes to convert CO_2 into a useful material or into an environmentally safe substance.

This combination of more efficient powerplants and carbon sequestration could help ensure that inexpensive and plentiful sources of fossil-fuel-based electric power continue to provide large economic benefits.

INVESTMENTS YIELD FAR-REACHING RETURNS

DOE's Fossil Energy Program has already demonstrated the far-reaching returns achievable with timely investments in new technology and in emergency preparedness.

In response to the Clean Air Act of 1970 and subsequent amendments, DOE and industry partners developed advanced emissions-reduction technologies for powerplants, including sulfur dioxide control technologies that proved to be dramatically more effective and lower in cost than the scrubbers initially deployed to meet the regulations. Similarly, DOE and its partners developed low-nitrogen-oxide burners that control emissions at one-tenth the cost of previously available technology and now account for a quarter of all coal-fired utility burners in the United States. Overall, technologies developed by DOE and its partners have reduced the costs of emissions controls by nearly 30% compared with earlier technologies, saving electricity consumers nearly $25 billion through 1995 on flue gas cleanup. The savings continue to accumulate, and are projected to top $300 billion by 2015. Thanks to intensive technology development, coal has remained the most affordable power generation fuel even as environmental control costs have risen.

Worldwide demand for electricity is projected to grow to 19 trillion kWh in 2015, most of which will be generated by coal. Industry funding has been leveraged in Fossil Energy programs to develop generation systems that will protect the environment, reduce the cost of electricity, and improve power generation efficiencies.

Similarly, since the 1980s, because of 3-dimensional seismic technologies, advanced drilling systems, and fracturing advances, our Nation has seen natural gas production increase by more than 14%, despite a 50% decline in wellhead prices. In the late 1970s, only one out of 10 exploratory wells found producible hydrocarbons; today, because of advanced technology, one out of four exploratory wells is successful.

DOE's Office of Fossil Energy has met its challenges with success: improving the environment while reducing compliance costs, enabling effective and efficient use of domestic energy resources, and enhancing our Nation's energy security. Now we are preparing for the formidable challenges of the next century.

Our challenges:

RECOVERING THE RICH OIL AND NATURAL GAS RESOURCES REMAINING IN DOMESTIC FIELDS

Ongoing innovations by DOE's Fossil Energy program will yield tools critical to economic exploration and production of these valuable domestic resources. Technologies developed by DOE are prolonging the life of domestic fields and also revealing new oil-bearing formations that previous technologies would have missed.

OPTIMIZING USE OF NATURAL GAS, WHICH HAS THE BEST ENVIRONMENTAL CHARACTERISTICS OF ALL FOSSIL FUELS

DOE is supporting the development of extraordinarily clean new end-use technologies such as high-efficiency turbines and fuel cells, which, coupled with new techniques of storing and transporting gas reliably and economically, can increase use of this plentiful domestic energy resource.

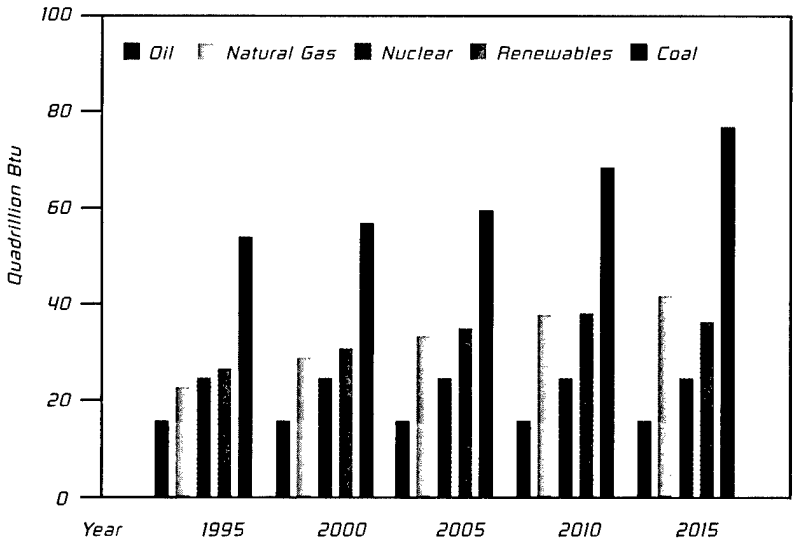
ACHIEVING ENTIRELY NEW LEVELS OF ENVIRONMENTAL PERFORMANCE FROM COAL-FIRED POWER SYSTEMS

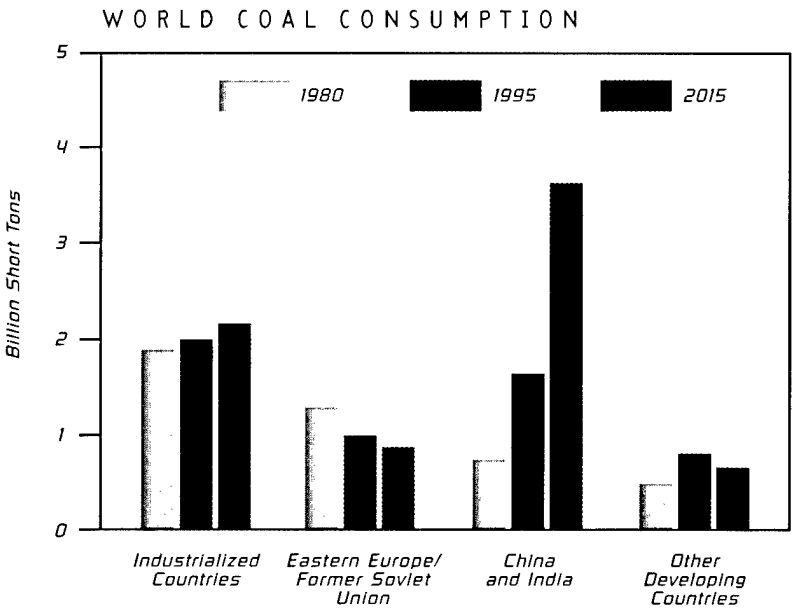
DOE has set a goal of developing coal power systems that can more than double today's powerplant efficiencies, producing energy, fuels, and chemicals while emitting virtually no pollutants or greenhouse gases into the atmosphere — the "Vision 21 Energyplexes."

MAINTAINING A RESPONSIVE DETERRENT TO OIL SUPPLY DISRUPTIONS

Over the course of nearly a quarter of a century, the United States has invested $20 billion in the world's largest emergency supply of crude oil — the Strategic Petroleum Reserve. Now, as a refurbishment program is completed, the Reserve has a life expectancy of another 25 years. The challenge will be to maintain a sufficient crude oil inventory to counter the continuing rise in oil imports.

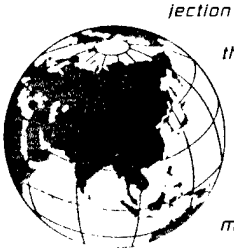
In 1995, 73% of the world's total CO_2 emissions from human activities came from the developed countries, most of it from energy use. The United States is the largest single source, accounting for 22%. During the next few decades, however, the population explosion and rapid economic development in developing countries will account for more than half of total global CO_2 emissions. China is expected to displace America as the largest emitter by 2015.





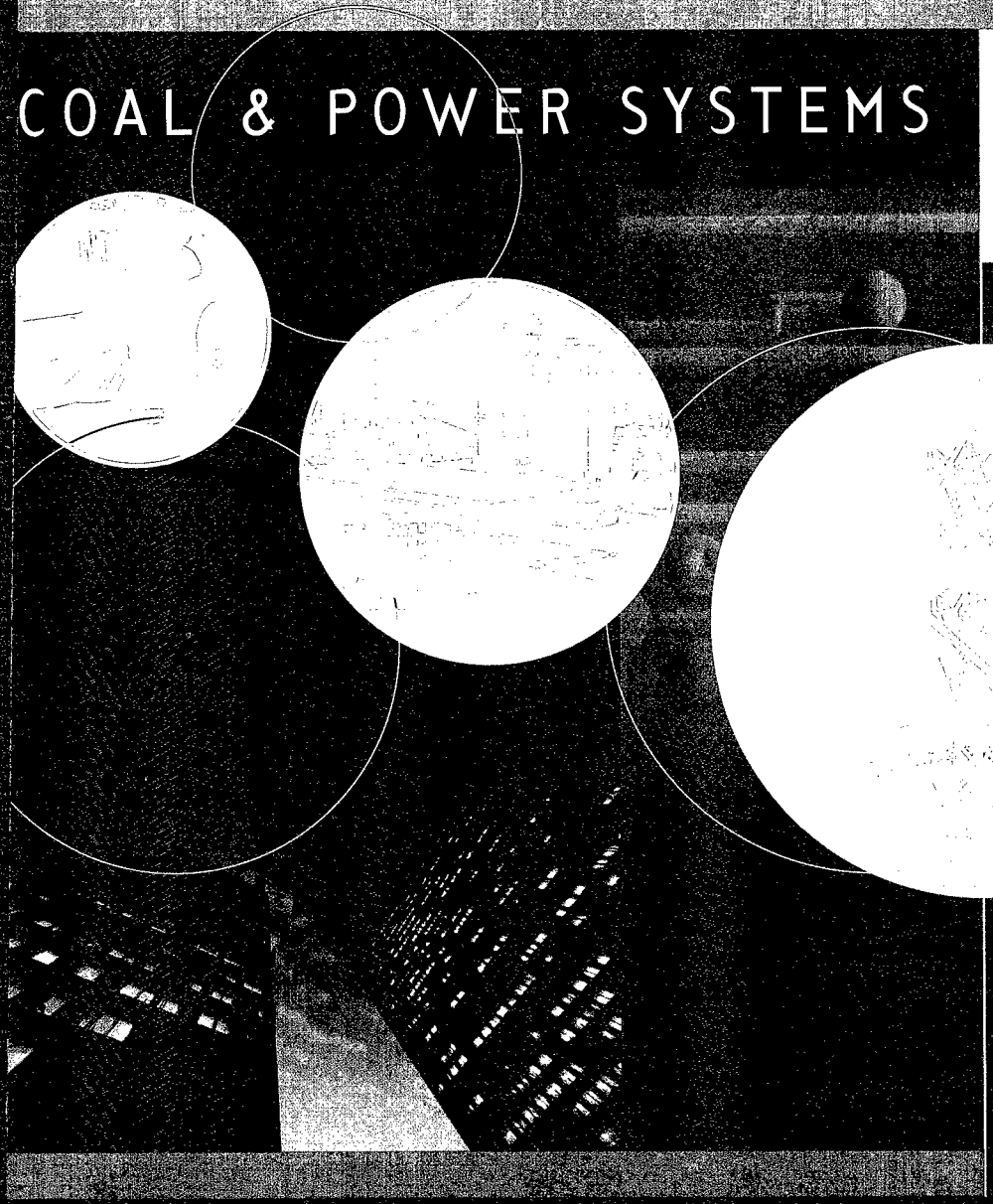
Source: Energy Information Administration, International Energy Outlook 1997

Americans spend more than $500 billion annually on fuels and power, making energy the largest single input to our Nation's economy outside of labor. Economical energy translates to affordable consumer products, competitive U.S. exports, and a growing, job-creating economy. Sales of clean power technologies worldwide could create 30,000 to 40,000 jobs if the United States wins a good percentage of the world market — which could reach as high as $750 billion over the next 20 years.



Coal today provides 75% of China's energy needs, and the projection is that it will continue to supply at least 60% of those needs through 2050. By 2015, India will be consuming nearly 280 million more tons of coal annually than it did in 1995. Clean coal technologies are critical to protecting the global environment while allowing worldwide improvements in living standards.

COAL & POWER SYSTEMS



21ST CENTURY TECHNOLOGIES FOR AN ERA OF EFFICIENCY

In the early years of the 21st century, the United States will begin building a new fleet of powerplants to meet rising electricity demand and to replace aging generating stations. Advanced technologies will be critical if these plants are to meet both the tighter emissions standards mandated by the 1990 Clean Air Act Amendments and future restrictions on the release of greenhouse gases. DOE expects that in the early 21st century it will be possible to build a coal-fired system that emits virtually no sulfur dioxide and nitrogen oxide pollutants, reduces CO_2 by 40%-47%, and cuts solid wastes by 40%-50%, all while producing electricity at a savings of 10%-20%.

Some of the most promising new clean power technologies being developed by DOE's Office of Fossil Energy are described on the following pages.

TECHNOLOGY FOR TOMORROW'S POWERPLANTS

LOW EMISSION BOILER SYSTEM

Designed to meet the demand for a coal combustion system that includes environmental controls as an integral, not retrofitted, component, the Low Emission Boiler System will push coal-fired power generation efficiencies into the 42%-44% range, while reducing smog- and acid-rain-forming air pollutants to well below Federal requirements. Now in its final phase of development, the system will incorporate state-of-the-art environmental controls into a supercritical boiler system.

PRESSURIZED FLUIDIZED-BED COMBUSTION

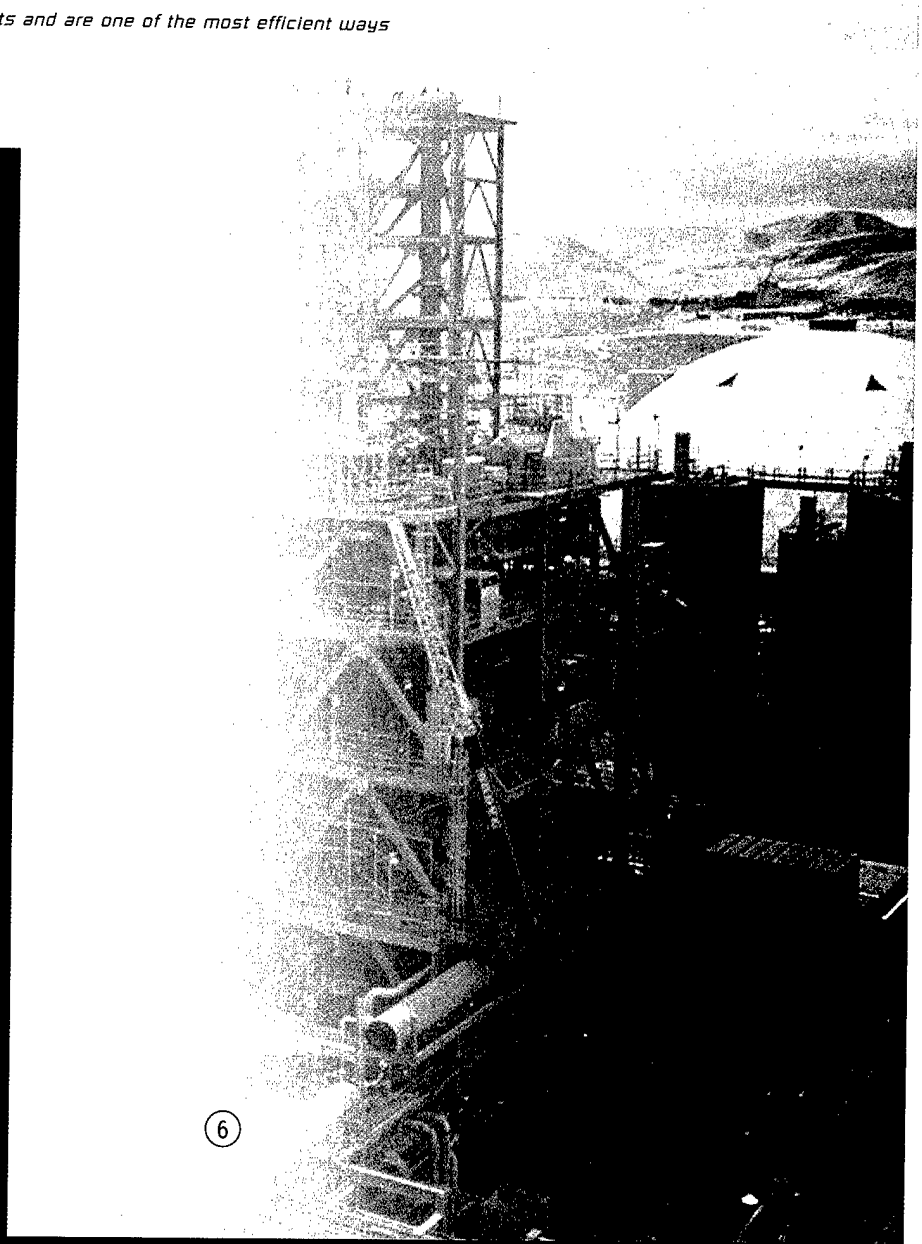
In pressurized fluidized-bed combustion, coal is burned at elevated pressures of 6 to 16 times atmospheric pressure to produce a high-pressure exhaust gas stream. The hot gases power a combustion turbine generator, while the waste heat is channeled to a conventional steam turbine generator. Combined efficiencies of over 50% are possible. Combustion temperatures are kept below the point at which most nitrogen oxide pollutants form, and sulfur dioxide is captured during turbulent mixing with limestone in the combustion chamber.

Pioneering a new era in clean power generation from coal, the Piñon Pine power project in Nevada is one of three major commercial-scale Integrated Gasification Combined Cycle plants operating today. Substituting gasifiers for traditional boilers, these systems burn high-pressure gases cleaned of virtually all pollutants and are one of the most efficient ways to produce electric power from fossil fuels.

FACILITATING U.S. TRADE IN ELECTRICITY

U.S. trade in electric energy with Canada and Mexico is increasing, bringing economic benefits and supply reliability to the United States and its trading partners. Within the Office of Fossil Energy's Coal & Power Program, an electricity import/export team is responsible for authorizing the export of electric energy and the issuance of permits for the construction, connection, operation, and/or maintenance of electric transmission facilities at international borders. The electricity import/export team acts as a facilitator for other governments and U.S. industry by supporting:

- Export promotion
- Information exchange and dissemination
- Technology and trade missions
- International agreements
- Joint forums
- Technology cooperation



INTEGRATED GASIFICATION COMBINED CYCLE

Gasification systems are among the cleanest and most efficient of the new technologies in DOE's R&D portfolio. In gasification-based power systems, coal is converted into a combustible gas. The gas is cleaned to remove over 99% of its sulfur and ash and 90% of its nitrogen impurities, then burned in the combustor of a gas turbine to produce power. Exhaust gases remain hot enough to drive a conventional steam cycle and produce more electricity. In the future, hydrogen from the coal gasification system may be used in an advanced, high-temperature fuel cell, which generates electricity electrochemically without using combustion. Integrated Gasification Combined Cycle systems with 45% efficiencies are currently in operation, and by 2005, systems will operate at efficiencies of 50% or more.

INDIRECTLY FIRED CYCLE

The Indirectly Fired Cycle system prevents coal combustion gases from contacting and damaging a gas turbine by using the gases to heat a clean working fluid such as air. The air, in turn, drives the turbine. Designs can involve high-temperature furnaces or innovative ceramic heat exchangers. Long-term efficiencies may approach 55%.

ADVANCED GAS TURBINES

As much as two-thirds of the U.S. generating capacity to be added in the next 15 years will likely involve natural-gas-fired turbines. Today's gas turbines are limited by the inability of their metal alloys to withstand temperatures over 2,350°F; furthermore, emissions controls, particularly for nitrogen oxides, often require expensive catalytic processes. DOE and its partners are completing development of a new generation of gas turbines that will break through the temperature limitations, reaching temperatures of 2,600°F while achieving ultralow emissions levels without add-on devices. These 21st century turbines could generate electricity from natural gas in stand-alone power stations or be integrated into the design of future powerplants based on coal gasification, pressurized fluidized-bed combustion, and fuel cells.

FUEL CELLS

Inherently clean and extremely efficient, fuel cells have the potential to supply reliable electricity while reducing emissions of CO_2 by as much as 60% below today's coal plants. Fuel cells operate without combustion, converting natural gas or other hydrogen-rich fuels electrochemically. If costs can be brought down and reliability increased, DOE expects advanced molten carbonate and solid oxide fuel cell systems to be market-ready in the first half of the next decade. Fuel cells could generate electricity in both central station and distributed power applications and, in the future, might be combined with advanced gas turbines to create a "hybrid" power system capable of achieving power-generating efficiencies of more than 70% and cogeneration efficiencies approaching 85%.

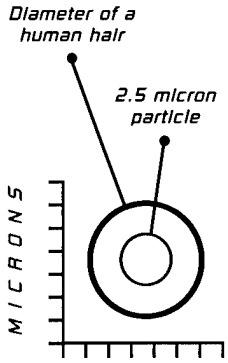
High efficiency and modular construction make fuel cells the power generation system of choice in distributed generation scenarios. The first commercial fuel cell installation in the northwestern U.S., this 200-kW ONSI phosphoric acid fuel cell unit helps to power a Spokane, Washington, hotel.

21ST-CENTURY ENVIRONMENTAL CONTROLS

The coal-fired powerplant of tomorrow may incorporate advanced subsystems, such as superclean flue gas scrubbers, ultralow nitrogen oxide burners, air toxics controls, and perhaps, in the longer term, innovative techniques for removing CO_2. The Office of Fossil Energy is carrying out programs to develop these advanced pollution-control devices while, at the same time, finding ways to manage solid wastes in the most environmentally sound way.

CONTROLLING AIR TOXICS

Current research suggests that most of the trace elements emitted by coal-fired powerplants and characterized as hazardous air pollutants by the 1990 Clean Air Act Amendments do not pose a health risk. But since the effect of airborne emissions continues to be uncertain, the Department is developing emissions-control alternatives with a particular focus on mercury. DOE's coal preparation program has taken on a broader context to encompass the removal of all potential pollutants, including mercury, from coal. Advanced physical, chemical, and possibly biological cleaning could offer utilities future environmental control options. Innovative sorbents and catalytic systems which convert flue-gas mercury into a chemical that can be removed by scrubber systems are being studied in the event that mercury regulations are imposed on the electric utility industry.



FILTERING EVEN SMALLER PARTICULATES

The Environmental Protection Agency has now revised the ambient standard for particulates to include those with diameters of less than 2.5 microns. This revision affects the allowable emissions of sulfur dioxide and nitrogen oxides from coal-fired powerplants. DOE and the EPA are implementing a new program to monitor and characterize more definitively the nature and source of such particles and to examine advanced control concepts for applicability to 2.5 micron particulate control.

SEQUESTERING CARBON DIOXIDE

While many technological tools exist that address pollution and climate concerns, achieving the ultimate goal of stabilizing atmospheric concentrations of greenhouse gases will require longer-range concepts for sequestering or reusing the CO_2 produced by industrial processes and fuel combustion. The Office of Fossil Energy has begun a high-priority program to develop innovative, low-cost technologies to meet this objective. Sequestration solutions can be terrestrial, such as injecting CO_2 into depleted oil and gas reservoirs, or marine, such as enhancing the natural uptake of carbon by oceans. In addition to physical storage, a variety of intriguing chemical or biological conversion methods may be feasible. Many of these sequestration systems will work best if combined with an advanced power generation system that concentrates the CO_2, making it easier to capture and process.

FUELS FROM COAL: AN INSURANCE POLICY FOR ENERGY SECURITY

A diversity of liquid fuels and valuable chemicals can be produced from coal. Liquid fuels from coal offer a potential supplement to current transportation fuels and, if costs can be reduced, these fuels could have a dampening effect on future world oil prices. DOE is developing more affordable and efficient techniques that rely on:

DIRECT LIQUEFACTION

The large, complex coal molecules are broken apart and converted to liquid fuels in a single process. Hydrogen is added to the coal to upgrade the liquid product, giving it characteristics comparable to petroleum.

INDIRECT LIQUEFACTION

Coal is first converted to a gaseous state using a coal gasifier, then the gaseous molecules are recombined into liquid products, including transportation-grade liquid fuels and alcohols.

Nearly two decades of R&D on coal conversion technologies have brought about a dramatic drop in their cost. In the 1970s the projected cost of coal liquids approached $60 per barrel, but today's technology has reduced this to under $35 per barrel. Recent advances, particularly the co-processing of coal with plastic or other hydrogen-rich waste materials, offer the prospects of further cost reductions, perhaps to below $25 per barrel.

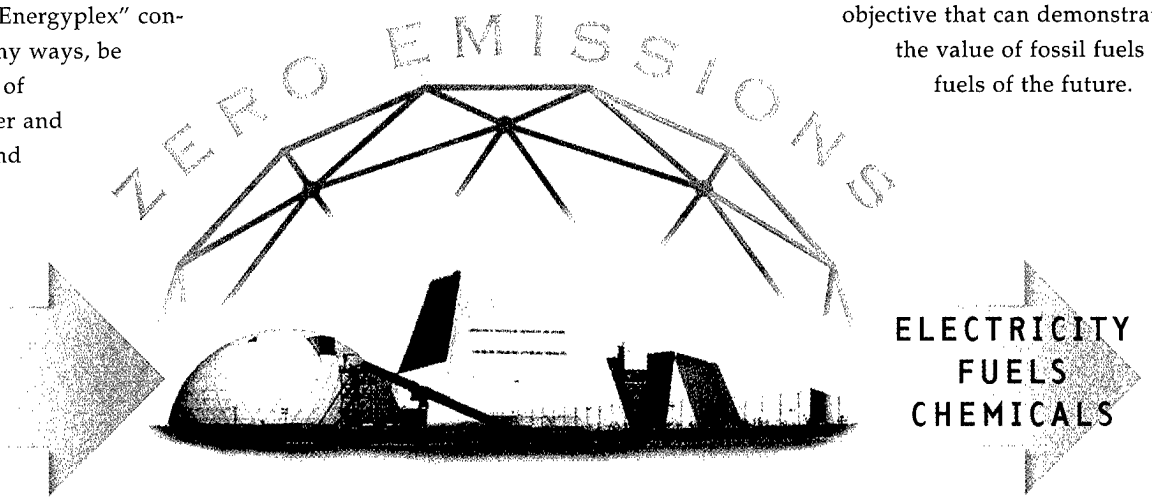
LOOKING OVER THE HORIZON: THE VISION 21 ENERGYPLEX

A modular facility capable of co-producing power, fuels, and chemicals, virtually eliminating smog- and acid-rain-forming air pollutants and solid waste, and capturing or recycling CO_2: this is the long-range vision guiding the Fossil Energy Coal and Advanced Power R&D Program.

This "Vision 21 Energyplex" concept will, in many ways, be the culmination of decades of power and fuels research and development. Within the "energyplex," the full potential of coal will be tapped through combinations of "energy islands," each producing power, fuels, and/or chemicals in the most efficient manner possible. Modules will incorporate coal gasifiers or advanced combustors, high-temperature cleanup systems, future generations of fuel cells and turbines, innovative carbon capture technologies, and perhaps concepts only just appearing on today's drawing boards. These modules will be reconfigurable, allowing the energyplex to be customized to meet geographical and market requirements.

The facility will be as close to a "zero discharge" energy system as possible. Sulfur dioxide and nitrogen oxide pollutants will be removed and converted into environmentally benign substances, perhaps fertilizers or other commercial products. CO_2 will be concentrated and either recycled or disposed of in geologically permanent natural sinks.

Developing such energyplexes will be a major challenge. But Vision 21 establishes a long-range goal. It provides a roadmap for evolving new, cleaner and more efficient energy products. It represents an ultimate objective that can demonstrate the value of fossil fuels as fuels of the future.



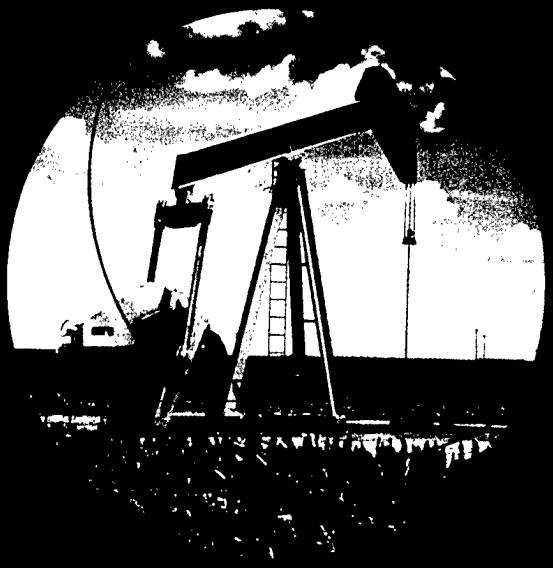
THE INCREASING BENEFITS OF TECHNOLOGIES SUPPORTED BY ADVANCED POWER R&D PROGRAMS

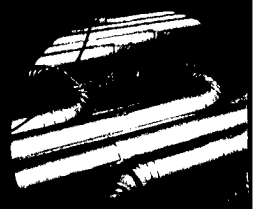
	2000	2005	2010	2015	VISION 21
EFFICIENCY	42-45%	48-55%	55%	60%	60% +
EMISSIONS*	1/3 NSPS	1/4 NSPS	1/10 NSPS	1/10 NSPS	Negligible
CO_2 REDUCTIONS	-29%	-42%	-42%	-47%	Zero CO_2
COST OF ENERGY**	10-20% lower	10-20% lower	10-20% lower	10-20% lower	10-20% lower

* NSPS- New Source Performance Standards, set by the Clean Air Act Amendments of 1990.
** As compared with currently available pulverized coal technology that would meet the same emissions standards.

NATURAL GAS & OIL

DOMESTIC OIL & GAS SUPPLIES





SUSTAINING A VITAL U.S. ENERGY INDUSTRY

Maintaining domestic energy supplies is crucial to America's economic health, yet one of our most serious energy problems is the premature abandonment of still-productive U.S. oilfields. Already, over 200 billion barrels – more than has been produced in the history of the U.S. oil industry – lies in domestic fields that have been abandoned. If the abandonment rate continues, as much as 70% of the Nation's remaining oil could be lost by the first decade of the 21st century. The high capital costs of re-establishing leases, reinstalling equipment, and drilling wells make it unlikely that abandoned fields will ever be reopened, even if oil prices rise.

Technologies developed in DOE-industry partnerships can provide cost-effective measures to sustain our oil and gas industries into the 21st century, reducing our increasing dependence on foreign, often unstable, sources.

INCREASING PRODUCTION OF VALUABLE U.S. RESOURCES

Investment in U.S. exploration and production is now less attractive to oil producers, particularly the major companies, than investment in easier-to-produce overseas reservoirs. As a result, independent companies now play an increasingly dominant role in the U.S. oil industry, drilling more than 80% of all new wells, producing 66% of the Nation's natural gas, and accounting for almost 40% of our domestic production.

For many independent producers, advanced technology holds the key to continued production. But smaller companies often operate on thin profit margins and rarely have been able to invest in the necessary R&D.

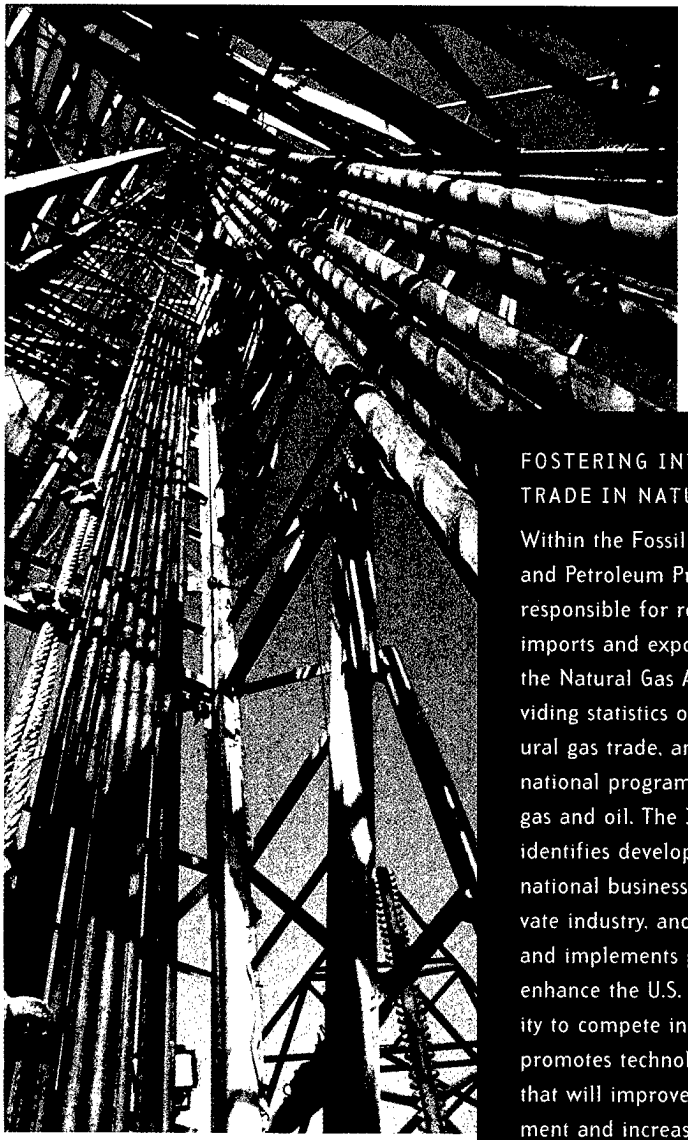
In this changing domestic market, DOE plays a crucial role in the development of these technologies, providing cost-sharing for higher-risk concepts that individual companies could not afford to finance on their own.

ADVANCED DRILLING, COMPLETION & STIMULATION SYSTEMS

DOE development efforts are focusing on innovative systems like steerable air percussion, slimhole underbalanced drilling, and advanced drilling fluids that increase the rate of penetration, and on mud pulse telemetry and electromagnetic measurement-while-drilling that improve accuracy. One product of this effort, the polycrystalline diamond drill bit introduced in the early 1980s, is considered to be one of the major advances in recent petroleum technology.

New stimulation technologies can be far more effective than current methods in reviving well productivity after it declines below economic levels. Innovative processes that improve reservoir permeability or flow conductivity focus largely on fracture propagation control and mapping. Technologies like CO_2/sand fracturing have raised productivity significantly, and a Field Fracture Multi-Site Facility run by DOE and the Gas Research Institute is providing valuable data on the shape and extent of hydraulically induced fractures and the responses of fracturing fluids.

Improved drilling and completion technologies also reduce formation damage, and this too helps to maintain well productivity. These technologies reduce drilling wastes and fluids use, some using a closed system that recycles materials. Importantly, they also impact a smaller acreage and prevent the disturbance of wetlands and sensitive surface environments.



FOSTERING INTERNATIONAL TRADE IN NATURAL GAS

Within the Fossil Energy Natural Gas and Petroleum Program, a team is responsible for regulating natural gas imports and exports under Section 3 of the Natural Gas Act of 1938; for providing statistics on North American natural gas trade, and for overseeing international programs concerning natural gas and oil. The Import/Export Office identifies developing export and international business opportunities for private industry, and develops programs and implements policies that will enhance the U.S. energy industry's ability to compete in foreign markets. It promotes technologies and solutions that will improve the global environment and increase U.S. energy security.

ADVANCED DIAGNOSTIC AND IMAGING SYSTEMS

If producers could pinpoint and recover the oil remaining in known fields, the United States could more than double its proven reserves of 22 billion barrels. New technologies could boost discoveries by as much as 45%. Yet another 25 to 60 billion barrels could be added by successful exploration in new fields.

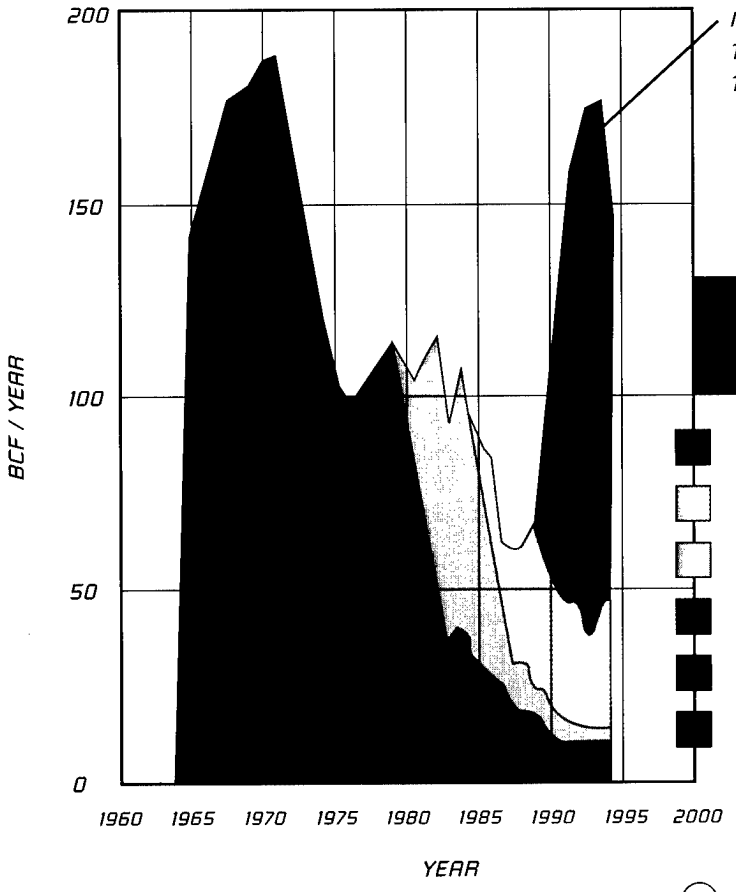
With advanced diagnostics and imaging technology, the costs and risks of exploring can be significantly reduced. For example, improved geophysical techniques to locate the most productive reservoir fractures can reduce the risk of dry holes and lead to more economically productive oil and gas wells. Envisioning how oil moves through pores and fractures in reservoir rock gives a producer valuable insights into how to design an effective field project. DOE's R&D is providing advanced tools to unlock the geologic secrets of a reservoir's architecture through reservoir modeling and simulation, geoscientific measurement, and gas reserves analysis. Some of the image technologies being developed include:

- Magnetic resonance imaging (MRI), to study how fluids flow through the rock
- Electromagnetic instruments, to create images of oil- and gas-bearing zones
- Computer-aided tomography (CAT) scan imaging, to examine reservoir rock and reveal bypassed compartments of hydrocarbons
- Supersensitive geophones, to detect "micro earthquakes" that reveal reservoir fractures
- Sophisticated computer models, to predict how a reservoir will respond to new oil and gas recovery approaches

TECHNOLOGY TRANSFER

If a technology is successful in one oilfield, it will be successful in a field with similar geology. Operators spread the word. In partnerships with oilfield producers, universities, State agencies, service companies, and consultants, DOE first sponsors high-risk projects, then transfers the information to commercial situations. In the 1990s, DOE helped establish the Petroleum Technology Transfer Council, an industry-led national network, to serve as a conduit for technology information, especially to smaller, independent producers.

Databases developed through Federal funding are also readily available to interested operators. A comprehensive national geoscience data repository system to preserve seismic, core, and log data is under way. Reservoir simulation and predictive models are available from DOE's National Petroleum Technology Office. Natural gas atlases are being completed, and DOE's Federal Energy Technology Center has begun distributing a free CD-ROM that provides one of the most comprehensive national databases to date on 9,014 of the Nation's natural gas reservoirs.



NATURAL GAS PRODUCTION IN SOUTH LOUISIANA FIELDS USING 3 D SURVEYS

Largely because of government-industry seismic and computational R&D, 3-D seismic imaging has boosted production in many mature fields. For example, the significant increase in natural gas production in 10 southern Louisiana gas fields during 1990 through 1994 is due to 3-D seismic technology.

Source: Gas Research Institute

RESERVOIR LIFE EXTENSION

When the first wells are drilled in an oilfield, natural pressure causes the oil to flow freely to the surface. When this primary production declines, operators often inject water or gases to maintain underground pressure and push more oil toward producing wells. These secondary recovery techniques are in use in most U.S. fields, but extending the productive life of reservoirs still further is essential to slow the rate of premature abandonment.

DOE is targeting several research efforts to improve secondary recovery techniques. Water may bypass large pockets of oil as it sweeps through a reservoir, and one goal is to find more effective ways to divert the waterflood to untouched areas.

Tertiary, or "enhanced," recovery turns to more novel approaches, and DOE's program aims to increase the effectiveness and predictability of these processes:

- Environmentally safe chemicals can be injected into a reservoir to reduce the tendency of oil to cling to surrounding rock.
- Polymers can make water thicker so that it drives more oil through a reservoir.
- Gases such as CO_2, nitrogen, and flue gas can be injected into the rock to move oil more easily through a reservoir.
- Microbes tough enough to survive the environment of an oil reservoir can produce gases or chemicals that increase the mobility of remaining oil.
- Thermal processes like steam injection can thin oil that is too thick to flow from some reservoirs.

Also within its Reservoir Life Extension Program, DOE supports an effort to capture some of the estimated 25% of recoverable natural gas now unattainable using conventional methods. Even after 50 years of commercial production, substantial gas resources remain in bypassed, incompletely drained, and untapped compartments. Through a combination of better exploration technologies, such as 3-D seismic and borehole tomography; and improved drilling and production technologies, such as horizontal drilling, DOE research is increasing production of this "secondary" gas. Already, in southwest Texas, techniques developed in the DOE program have increased proved natural gas reserves by about 4 trillion cubic feet, potentially worth nearly $1.4 billion in gross production revenues.

NATURAL GAS STORAGE

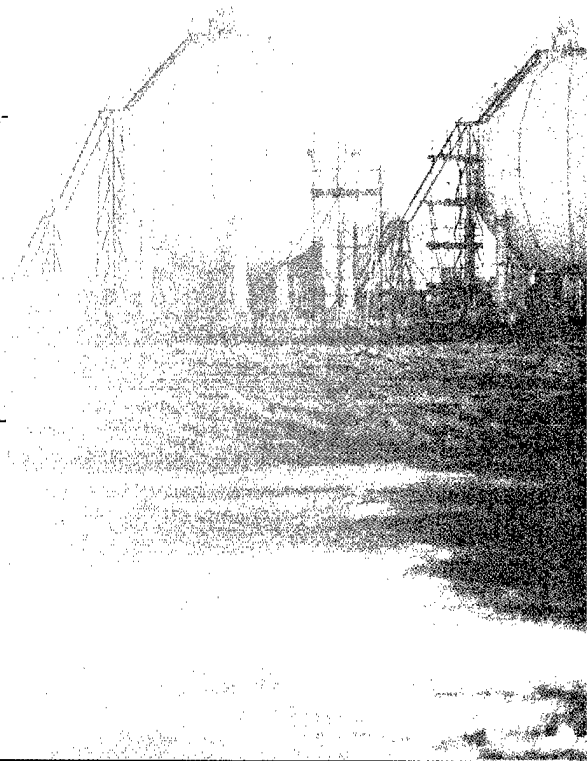
Adequate, responsive, and cost-efficient underground storage is vital to maintaining the confidence level of natural gas consumers. Stored gas can supplement pipeline capacity during periods of heavy demand and serve as backup supply during an interruption in wellhead production. Today there are more than 17,000 gas storage wells at 375 sites around the country.

DOE's program supports the development of technology that will improve underground storage deliverability, lead to more efficient reservoir management, and develop advanced storage concepts, alternative storage methods, and a national deliverability capacity and storage model.

NATURAL GAS PROCESSING

As the United States considers future sources of liquid fuels, the possibility of turning natural gas into liquids has seen a recent surge of interest. Particularly intriguing is the possibility that huge supplies of distant natural gas sources, such as those in the North Slope region of Alaska, might be converted to liquid forms that could be economically transported through the existing Trans Alaska Pipeline. Similarly, remote sources of gas offshore might become more marketable if a low-cost means could be found to convert them to a more easily transportable liquid form. DOE's Natural Gas Processing Program has expanded its support of innovative concepts that could make gas-to-liquids conversion more economically attractive. Research in ceramic membrane technology, for example, could lower the cost of producing the pure oxygen necessary to the gas-to-liquids process.

Improving the economics of gas-upgrading technologies is another priority in this program. About one-third of the Nation's natural gas resource does not meet pipeline specifications. Impurities such as CO_2, nitrogen, and hydrogen sulfide must first be removed. DOE is examining new gas purification technologies that remove inert or hazardous contaminants at much lower costs than are possible today. Such technologies could make currently unaffordable gas economically marketable.



OIL AND GAS ENVIRONMENTAL RESEARCH AND ANALYSIS

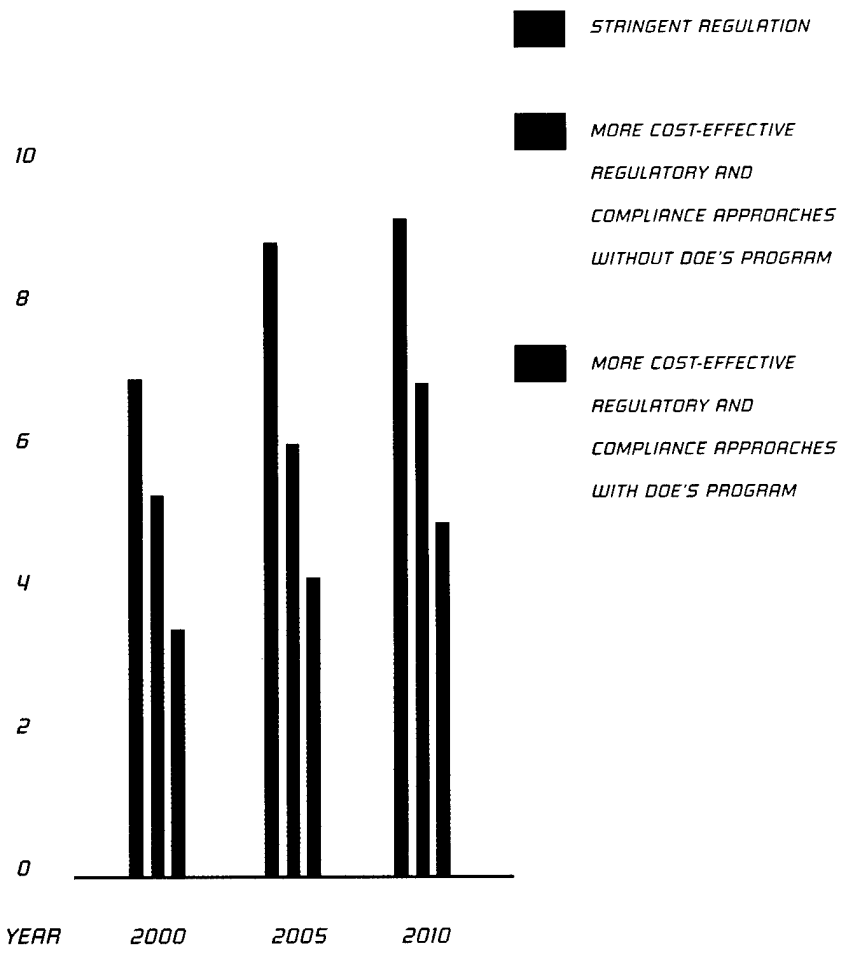
Simplification of the regulatory framework, along with more affordable compliance technologies, will ensure environmental protection in oil and gas operations. The U.S. exploration and production industry currently spends more than $1.5 billion a year to comply with environmental protection requirements. Between 75% and 90% of the oil refining industry's capital equipment budget is used to comply with environmental regulations.

DOE has undertaken an intensive effort to ensure that environmental regulations are scientifically sound and based on an adequate assessment of environmental risks. Issues ranging from the disposal of produced water and wastes in oil and gas fields to the control of small particulates and other emissions from oil refineries are among the topics addressed in DOE's program.

Failure to make environmental regulations more site-specific and scientifically grounded could reduce production by 330,000 barrels of oil per day or 120 million barrels per year in 2020, resulting in even higher oil imports. But by furthering risk-based, streamlined regulations based on credible scientific information, and by developing lower-cost compliance technologies, the DOE program could ultimately:

- Decrease cumulative industry compliance costs through 2010 by as much as $16 billion
- Maintain production of up to 60,000 barrels per day of oil
- Increase gas production by 900 billion cubic feet per year
- Contribute over $8 billion to Federal and State treasuries by 2010
- Add as many as 11,000 jobs to the economy

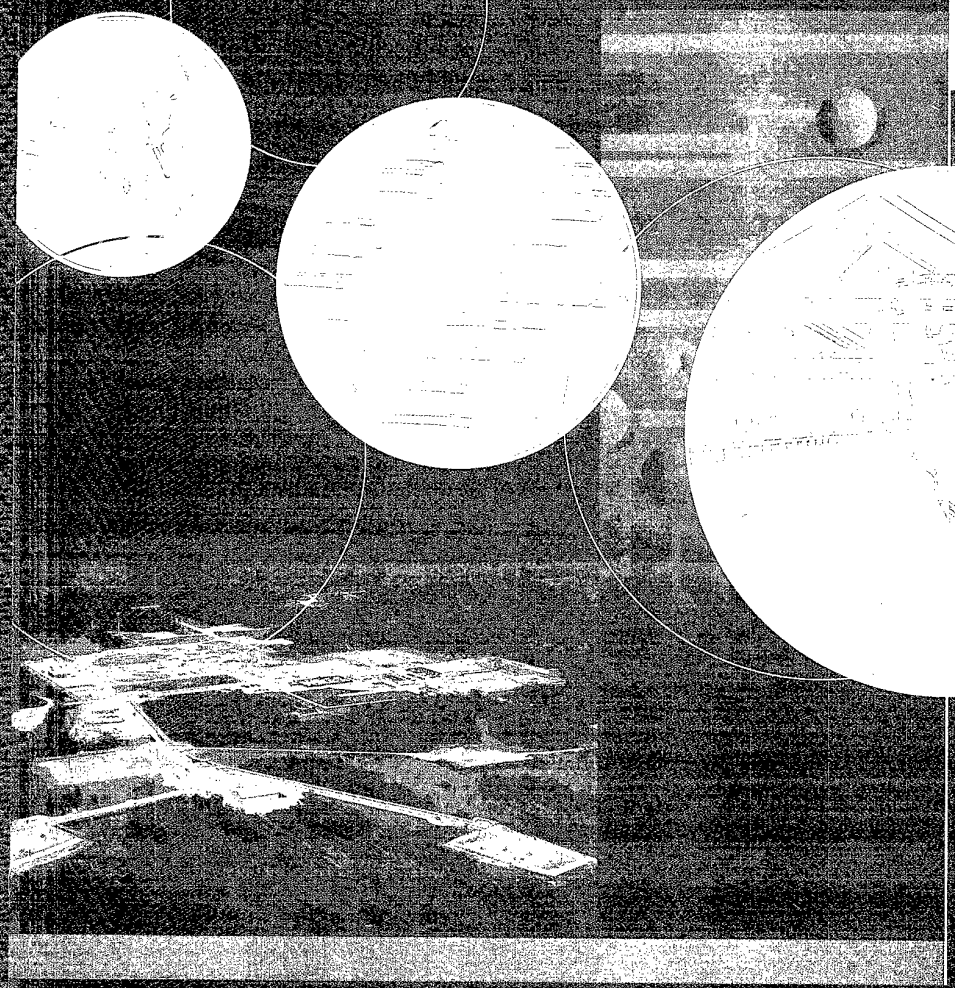
RISING ENVIRONMENTAL COMPLIANCE COSTS
(IN $ BILLIONS)



OIL AND GAS MODELING AND ANALYSIS

Decision makers in Federal, State and local governments require timely, accurate information as they define the future course of America's energy industry. To provide this information in the oil and natural gas sectors, DOE carries out a program of modeling and analysis across the full spectrum of petroleum activities, from exploration and production to processing and delivery. It provides estimates of potential domestic oil and gas production in a wide range of scenarios encompassing different technologies, economic factors, and legislative and regulatory environments, using a suite of engineering and economic analysis models.

PETROLEUM RESERVES



FIRST LINE OF DEFENSE AGAINST OIL IMPORT DISRUPTIONS

The United States relies on imports for more than half of its total petroleum supplies, and this level of dependence is forecast to increase over time. Given the interdependence of world oil markets, the U.S. and its allies are at risk of economic instability and strategic vulnerability from any disruptions in the global supply. A strategic oil reserve is the best way to protect the Nation from this risk, and its very existence serves as a visible deterrent to any potential threat. Maintaining control of as-yet largely untapped petroleum and oil shale fields also provides a strategic reserve of domestic supplies and an ongoing source of income.

THE STRATEGIC PETROLEUM RESERVE

THE STRATEGIC PETROLEUM RESERVE — CENTERPIECE OF THE NATION'S ENERGY SECURITY PROGRAM

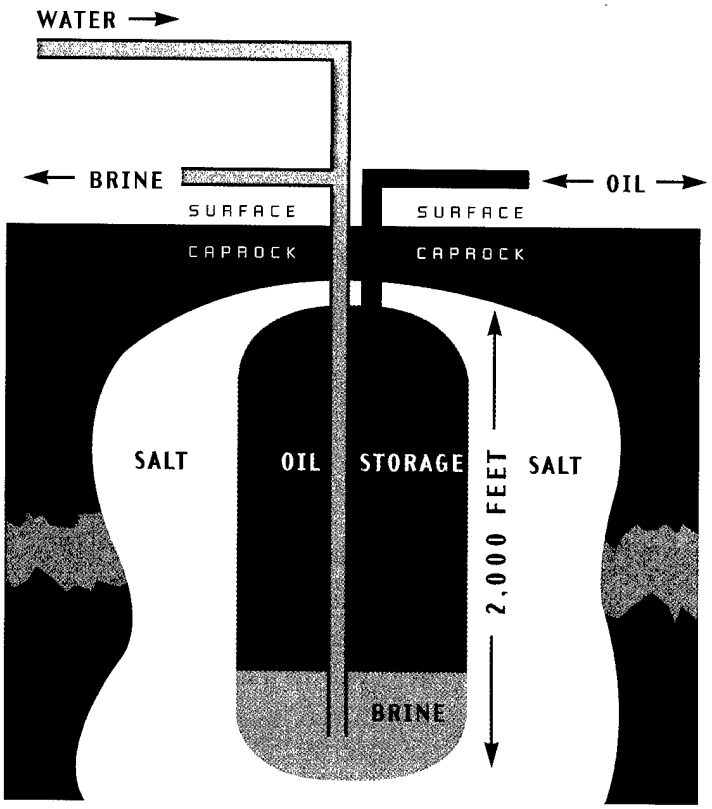
The Strategic Petroleum Reserve is the largest stockpile of emergency crude oil in the world. Operated and maintained by DOE's Office of Fossil Energy, the Reserve is the Nation's first line of defense against an interruption in oil supplies. More than 550 million barrels of crude oil are stored in huge underground salt caverns along the coast of the Gulf of Mexico and can be supplied quickly and efficiently to the Nation's refineries if commercial supplies are disrupted. Originally designed in the mid-1970s for a 20-year lifetime, the Reserve is completing a refurbishment and modernization program that will extend its usefulness at least through the year 2025.

DEVELOPED AS INSURANCE AGAINST GLOBAL INSTABILITY

The 1973 Arab oil embargo was the principal catalyst for the creation of the oil reserve, but such a reserve had been first advocated as early as 1944. President Truman's Minerals Policy Commission also proposed a strategic oil supply in 1952, as did President Eisenhower following the 1956 Suez crisis. The Cabinet Task Force on Oil Import Control recommended a similar reserve in 1970. It was authorized in 1975 with passage of the Energy Policy and Conservation Act.

Crude oil, not refined oil, is stored, as it is more versatile and not subject to deterioration. Deep underground salt dome caverns were chosen to house the inventory because they offer the best security and are the most affordable means of storage, costing up to 10 times less than above-ground tanks and 20 times less than hard rock mines.

Storage locations along the Gulf Coast were selected because they provide the most flexible means for connecting to the Nation's commercial oil transport network. Strategic reserve oil can be distributed through interstate pipelines to 45% of the Nation's oil refineries or loaded into ships for transportation to other U.S. refineries.



Strategic oil reserves are stored in huge caverns hollowed out of salt formations by solution mining. Water pumped into the formation dissolves the salt and is withdrawn as brine. Oil is pumped into the cavern for safe storage, and withdrawn at need by pumping fresh water into the base of the cavern.

RESERVE OIL CAN BE WITHDRAWN SWIFTLY AT NEED

While the Strategic Petroleum Reserve has been tested several times, it has been used only once for emergency drawdown purposes. During Operation Desert Storm in 1991, President Bush ordered the Reserve's first-ever emergency use as part of an internationally coordinated precautionary move to counter possible upswings in world oil prices. The drawdown and distribution system worked virtually flawlessly. Within 24 hours of the Presidential direction, DOE had set into motion a plan to sell 33.75 million barrels of crude oil. As world oil supplies and prices stabilized, actual sales were reduced to 17.3 million barrels to 13 companies. The Desert Storm drawdown was a dramatic demonstration of the value and impact of the emergency stockpile, both in real terms and as a key tool of foreign policy.

At full readiness, the Strategic Petroleum Reserve can distribute crude oil to the market at a maximum sustained rate of nearly 4 million barrels a day for up to three months. As caverns are emptied, the drawdown rate decreases proportionately. A full-scale drawdown could supply some level of crude oil to the market for as long as a year.

By tanker, barge, or pipeline, strategic reserves can be distributed fast. Each distribution complex is tied into the Nation's commercial oil transport network.

CURRENTLY AND PERPETUALLY IN A STATE OF READINESS

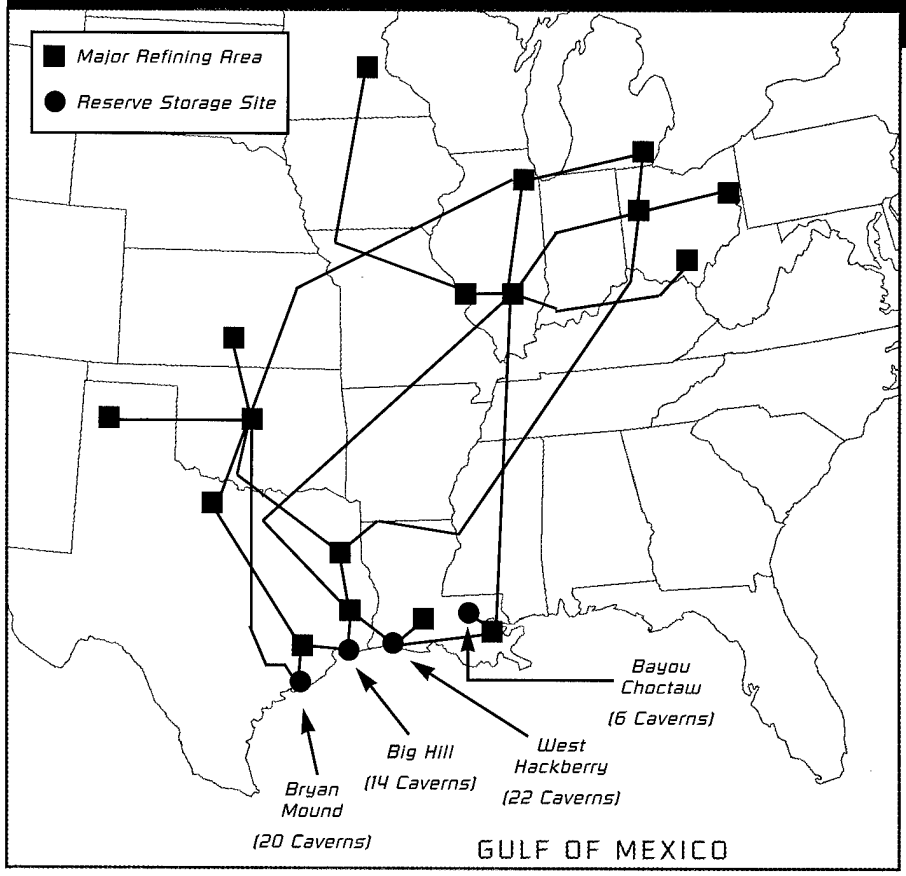
Today, the Strategic Petroleum Reserve holds more than 550 million barrels of crude oil. At its peak, its inventory has been 592 million barrels, but in the mid-1990s some of this inventory was sold in nonemergency offerings to finance the decommissioning of an environmentally unsound site and, by Congressional direction, for budget offsetting purposes.

Fill was suspended in 1995 as budgets tightened and more resources were devoted to refurbishing equipment and extending the life of the complex. This major life-extension program included replacing or renovating pumps, piping, and other key components.

The facilities and crude oil together represent a more than $20 billion national investment. The Strategic Petroleum Reserve is extremely cost-efficient to operate and maintain due to its storage technology, centralized operations, and economies of scale. On a per-barrel basis, it is the lowest-cost oil reserve in the world. DOE is currently pursuing an initiative to further increase its cost efficiency by leasing several distribution facilities that are currently underused. Also, the United States has offered other nations the opportunity to lease a portion of the 110 million barrels of unfilled cavern capacity for their own strategic oil storage programs.

The Strategic Petroleum Reserve is maintained in a high state of operational readiness in order to respond rapidly to an energy crisis. It embodies a commitment to energy security that is just as relevant in today's world as it was over 20 years ago.

MARINE AND PIPELINE DISTRIBUTION CAPABILITIES



THE NAVAL PETROLEUM AND OIL SHALE RESERVES

The historic sale of the Elk Hills Naval Petroleum Reserve was concluded when Energy Secretary Federico Peña and Occidental Oil & Gas Chief Executive David Hentschel signed the final sale documents on February 5, 1998. Assistant Energy Secretary Patricia Godley, who oversaw the sales process, watches the culmination of more than two years of effort.

THE LARGEST PRIVATIZATION IN THE HISTORY OF THE UNITED STATES GOVERNMENT

For much of the 20th century, the Naval Petroleum and Oil Shale Reserves served as a contingency source of fuel for the Nation's military. Set aside in the early 1900s, these government-owned petroleum and oil shale properties were originally envisioned as a way to provide a reserve supply of crude oil to fuel U.S. naval vessels that once depended heavily on crude oil. But in the latter part of the century, military fuel needs changed, and the strategic value of the Reserves began to diminish. In the 1970s, as the Nation looked for ways to maximize its domestic oil supplies, the oil fields of the Reserves were opened up for commercial production.

Today the Naval Petroleum and Oil Shale Reserves no longer serve the national defense purpose envisioned in the early 1900s. As a result, in 1996 the largest of the Federal properties — the government's share of the Elk Hills field in California — was offered for commercial sale. On February 5, 1998, DOE completed its sale to Occidental Petroleum Corporation for $3.65 billion in the largest privatization of Federal property in the history of the United States.

At the same time, the Department of Energy is transferring two of the Naval Oil Shale Reserves, both in Colorado, to the Department of Interior's Bureau of Land Management. Like many other federally owned lands, these properties will be offered for commercial mineral leasing, primarily for natural gas production and future petroleum exploration.

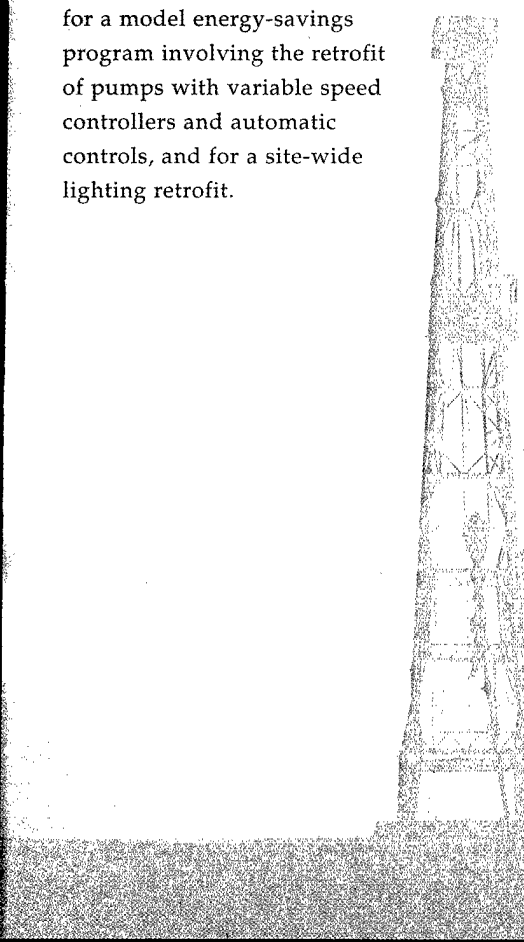
TWO DECADES OF STEWARDSHIP

For the two decades that the U.S. Department of Energy managed the Naval Petroleum and Oil Shale Reserves, the properties served valuable functions not only as a source of revenue for the U.S. Treasury but also as a model for improved oil field practices.

The Elk Hills field, opened for commercial production in 1976, eventually became one of the Nation's 11 largest oil and natural gas fields. In September 1992, the field produced its one-billionth barrel of oil, becoming only the thirteenth field in the Nation's history to reach that milestone. While managed by DOE, Elk Hills generated nearly $13 billion in profits for the U.S. Treasury. In 1994, petroleum engineers were able to halt the field's historical 8% production decline by a program of gas and water injection combined with the first large-hole horizontal wells to

be drilled in California. In November 1994, the first cogeneration facility at a DOE site went on-line at Elk Hills, using natural gas from the field to generate on-site electricity and heat. The facility allowed DOE to begin immediately reducing its Elk Hills electricity bill by more than $1 million a month.

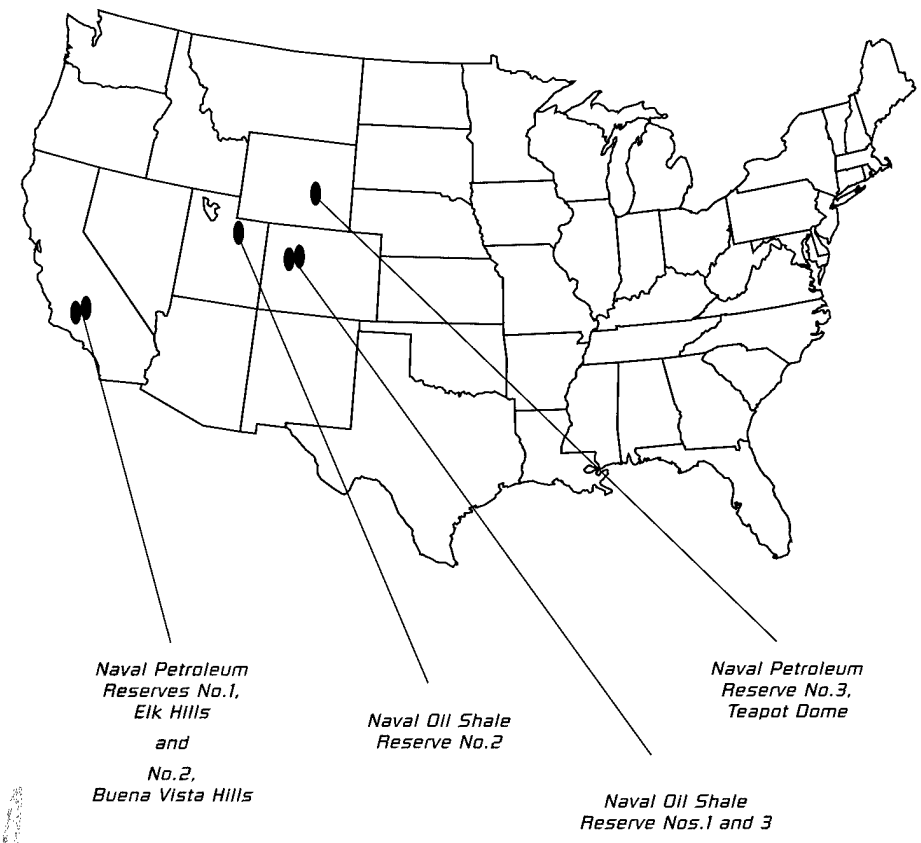
The Elk Hills field also served as a model for environmental protection. In 1989, field operators completed a two-year project to replace existing cylinder heads on large natural gas engines and smaller field compressors with new, lean-burn, pre-combustion-chamber technology. The refurbishment reduced nitrogen oxide emissions by 70%, the equivalent of more than 12,000 pounds per day. In 1993 the local chapter of the American Lung Association awarded Elk Hills its Clean Air Award for reductions in vehicle emissions achieved by an extensive program of truck and van-pool conversions to natural gas. Elk Hills engineers were also the recipients of Federal Energy Efficiency Awards for the fleet conversion program, for a model energy-savings program involving the retrofit of pumps with variable speed controllers and automatic controls, and for a site-wide lighting retrofit.



Following the sale of Elk Hills and the transfer of the two Colorado oil shale reserves, DOE retains oversight of three properties in the Naval Petroleum and Oil Shale Reserves:

- **The Teapot Dome Naval Petroleum Reserve #3 in Wyoming** — a small stripper well oilfield that the Department will maintain until it reaches its economic production limit, probably around the year 2003. Environmental remediation efforts are underway, and a portion of the field is being used as the Rocky Mountain Oilfield Testing Center, where independent oil companies and others can come to test exploration and production innovations in an actual field setting.
- **The Buena Vista Hills Naval Petroleum Reserve #2 in California** — a "checkerboard" pattern of government and privately owned tracts adjacent to the Elk Hills field. Of the 50 tracts owned by the government, nearly 90% are leased by private oil companies.
- **The Naval Oil Shale Reserve #2** — an 88,890-acre tract located in a remote area of Utah. The property has shown geologic potential for oil and natural gas production, although the acreage's hydrocarbon potential is still unexplored. Portions of the reserve hold cultural significance to local Native American tribes, and some of the property is included in the Department of the Interior's Utah Wilderness Reinventory.

NAVAL PETROLEUM AND OIL SHALE RESERVES



DOE FOSSIL ENERGY FIELD OFFICES

The Office of Fossil Energy has five major field offices. R&D projects are overseen by the Federal Energy Technology Center at Morgantown, West Virginia, and Pittsburgh, Pennsylvania, the National Petroleum Technology Office at Tulsa, Oklahoma, and the Albany Research Center in Albany, Oregon. Field offices also manage the Strategic Petroleum Reserve and the Naval Petroleum and Oil Shale Reserves.

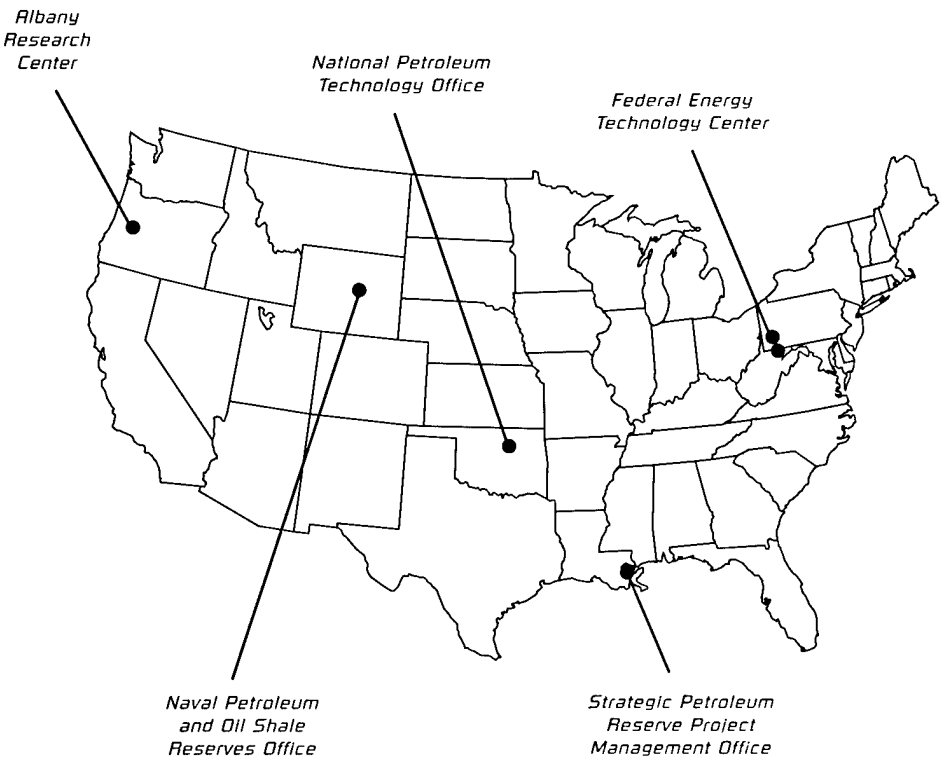
THE FEDERAL ENERGY TECHNOLOGY CENTER, co-located in Morgantown, West Virginia, and Pittsburgh, Pennsylvania, is responsible for managing technology development efforts for coal and natural gas. Included in its portfolio are (1) advanced power generation systems, (2) advanced fuels technology, (3) natural gas exploration and production, (4) advanced environmental control systems, and (5) fundamental fossil energy research conducted by universities and institutions.

THE NATIONAL PETROLEUM TECHNOLOGY OFFICE, formerly the Bartlesville Project Office, relocated to Tulsa in the spring of 1997. It oversees programs in oil recovery field demonstrations, petroleum exploration and production technology, petroleum-related environmental programs, and technology transfer.

THE ALBANY RESEARCH CENTER in Albany, Oregon, became part of DOE in 1996 when its former parent agency, the Bureau of Mines, was abolished by Congress. The Center is one of the Nation's preeminent laboratories for materials research.

THE STRATEGIC PETROLEUM RESERVE PROJECT MANAGEMENT OFFICE in New Orleans, Louisiana, has day-to-day responsibility for overseeing the storage sites and transportation systems that make up the federally owned stockpile of emergency crude oil.

THE NAVAL PETROLEUM AND OIL SHALE RESERVES OFFICE in Casper, Wyoming, oversees properties remaining under DOE's authority, including the Teapot Dome Naval Petroleum Reserve #3 in Wyoming and the Naval Oil Shale Reserve #2 in Utah. A small office is also maintained in Bakersfield, California, to manage remaining post-sale environmental responsibilities for remediation at the Elk Hills site.



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