

MATURE REGION, YOUTHFUL POTENTIAL

Oil and Natural Gas Resources in the
Appalachian and Illinois Basins

*A Report by the Appalachian and Illinois Basin Directors
of the Interstate Oil and Gas Compact Commission*

The United States is the world's third-largest producer of oil and second-largest producer of natural gas. Prospects for future production from the Appalachian and Illinois basins remain promising, despite the maturity of these basins. The Appalachian basin occupies more than 180,000 square miles, while the Illinois basin encompasses approximately 53,000 square miles. Together, these basins span 10 states — Kentucky, Maryland, New York, Ohio, Pennsylvania, Virginia, West Virginia, Tennessee, Illinois, and Indiana.



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This report was developed by the Appalachian and Illinois Basin Directors in cooperation with the Interstate Oil and Gas Compact Commission (IOGCC) and the U.S. Department of Energy's Office of Fossil Energy and National Energy Technology Laboratory. It is intended to serve as a reference source for government and industry decision makers.

The IOGCC represents the governors of 30 member and 7 associate member states. The IOGCC's mission is to promote conservation and efficient recovery of domestic oil and natural gas resources while protecting health, safety, and the environment. The group offers a forum for government, industry, environmentalists, and others to share information and viewpoints.



Overview

Secure energy for the nation, economic benefits for Eastern states

Making optimal use of available domestic fossil fuel resources is key to ensuring adequate supplies of energy for American consumers. This imperative has brought renewed focus to the significant oil and natural gas resources still remaining in America's oldest producing areas: the Appalachian and Illinois basins.

As our nation's appetite for oil and natural gas continues to grow, so does our dependence on imports. During the past three decades, U.S. demand for crude oil and natural gas has increased steadily while domestic production has declined (crude oil) or remained flat (natural gas). The gap between domestic supply and demand is expected to continue growing, potentially resulting in even greater dependence on imports in the future.

Our "most drilled but least explored" basins deserve a fresh look. After more than a century, the Appalachian and Illinois basins still contain at least as much oil and natural gas as have been produced to date. Estimates of remaining technically recoverable resources, including proved reserves, are in the range of 4.8 billion barrels of oil and 79 to 96 trillion cubic feet of natural gas. The majority of remaining hydrocarbon resources in these basins exists in unconventional settings – primarily in coal seams, Devonian-age shales, and low-permeability (tight) gas sands – and previously untapped deeper formations. In the longer term, the basins could also provide further hydrocarbon resources from oil sands and oil shale. In the future, with their large untapped potential resources and proximity to major markets, the basins are positioned for an important role in increasing America's energy security.

New plays are attracting heightened interest in exploration and production in the region. Applying new technology and concepts is resulting in a wide range of new activities in the basins. *Coalbed natural gas* – a plentiful resource throughout both basins – is being pursued economically using conventional drilling and completion techniques as well as advanced multilateral technology and horizontal drilling. Advanced geophysical analyses and drilling cost reductions are enabling operators in several areas to take another look at the deep *Trenton/Black River play*, which extends through both basins. New reservoir stimulation and horizontal drilling are enabling operators to revisit old shale (like the *New Albany Shale*) and tight gas sand (such as the *Clinton/Medina*) plays, and 3D seismic is helping in the pursuit of untapped hydrocarbon resources in *pinnacle reefs*.



Eastern states already benefit significantly from regional oil and natural gas production.

States in the region are highly dependent on oil and gas production for revenues from severance and state corporate income taxes. In 2004, oil and gas production in the basins was valued at \$5.9 billion, and with rising prices, this value has continued to increase. Throughout the entire value chain from initial development and production to end use, income and investment related to the oil and natural gas industry are critical components of the region's economic vitality. Many believe that production in the Appalachian and Illinois basins can be reinvigorated, yielding substantial returns to regional economies in the Eastern states as well as to the nation's economic and energy security. Nearly 375,000 people are employed in the oil and natural gas industry in the Appalachian and Illinois basins states, and regional industries employing millions more rely on these fuels for feedstocks or process heat.



Pathway to rejuvenating the basins

Collaborative basin-wide strategies, driven by public-private partnerships as well as state governments, will be essential to bringing more of the region's vital oil and natural gas resources to market. Five prerequisites must be addressed, using strategies such as those outlined below:

Prerequisite 1: Technology progress

- ✓ Extending the life of existing wells and fields through advanced technology
- ✓ Improving fracture detection
- ✓ Applying more advanced 3D seismic imaging
- ✓ Tapping unexplored deep reservoirs through new drilling and completion techniques
- ✓ Exploiting opportunities to develop coalbed natural gas and other unconventional resources
- ✓ Expanding use of advanced enhanced recovery techniques
- ✓ Supporting technology transfer across the region
- ✓ Stimulating investment opportunities

Prerequisite 2: Access to resources

- ✓ Increasing access to resources on public lands in an environmentally sound manner
- ✓ Resolving mineral rights conflicts between coal and oil and natural gas resources
- ✓ Addressing the unique access issues in urban and suburban areas
- ✓ Implementing energy education programs to increase public understanding of oil and gas operations

Prerequisite 3: Infrastructure expansion

- ✓ Expanding pipeline capacity
- ✓ Expanding natural gas storage capabilities
- ✓ Improving the capacity of gas gathering and processing

Prerequisite 4: Access to high-quality data

- ✓ Public-private partnerships between geologic surveys, other state agencies, and industry
- ✓ Continuing innovation in data management, e.g., risk-based data management system

Prerequisite 5: Environmental stewardship

- ✓ Strong and responsive regulatory programs
- ✓ Cost-effective regulatory strategies
- ✓ Continuing oil field and pipeline emergency response programs and training
- ✓ Communication among state and federal regulatory agencies to improve program efficiency and effectiveness

The Opportunity

Taking a second look at the “most drilled, least explored” basins in the world

The Appalachian and Illinois basins – the birthplace of the modern petroleum industry – are probably the most extensively drilled and mature hydrocarbon basins in the world. Does this mean that oil and natural gas resources from the region have been exhausted? The answer is a resounding *no*. The Appalachian and Illinois basins are mature, yet they still have a youthful potential. Oil and gas explorer Richard Beardsley, a geologist with extensive experience in the Appalachian basin, calls it the “most drilled and least explored” basin in the world.¹

Annual oil production for most Appalachian and Illinois basin states peaked before 1910, and overall natural gas production in the region began to decline around 1930. Notable exceptions include Virginia, where coalbed natural gas production began in 1990 and has increased every year since, and Kentucky, where gas production has recently peaked, growing steadily since reaching a low in 1983.

This recent natural gas production hints at the remaining potential of the region. So do recent resource discoveries in the Trenton/Black River formations in New York and West Virginia, the coalbed natural gas potential throughout the region, new production from the New Albany Shale gas play in southern Indiana and northern Kentucky, oil discoveries in pinnacle reef formations, resources in tight gas sands, and the potential application of carbon dioxide injection to enhance oil recovery in old oil fields. All are clear signs that as far as future oil and gas production potential in the Appalachian and Illinois basins is concerned, the story may be far from over.

Cumulatively, the basins have produced more than 5 billion barrels (BBbl) of oil and 50 trillion cubic feet (Tcf) of natural gas. Yet after more than a century of production, equal or greater quantities of resources are still waiting to be tapped. The Appalachian basin is the largest onshore basin in the United States in terms of area, and much of the basin remains relatively unexplored. While determining the extent of hydrocarbons in the basins is not an exact science, current estimates of remaining technically recoverable resources (including proved reserves) are in the range of 4.8 BBbl of oil and 79 to 96 Tcf of natural gas.

What are an Mcf, MMcf, Bcf, and Tcf?

Natural gas is sold in units of a thousand cubic feet (Mcf, using the Roman numeral for one thousand). Units of a million cubic feet (MMcf), billion cubic feet (Bcf), or trillion cubic feet (Tcf) are used to measure larger quantities. The United States currently consumes about 22 Tcf annually. A Tcf is enough natural gas to:

- Heat 15 million homes for one year
- Generate 100 billion kilowatt-hours of electricity
- Fuel 12 million natural-gas-fired vehicles for one year

How much is a Bbl?

A barrel (Bbl) of crude oil or natural gas liquids is equal to 42 U.S. gallons. The United States currently consumes about 20 million barrels (MMBbl) of oil per day, or 7.3 billion barrels (BBbl) per year.

What is a play?

A play is a set of known or postulated natural gas or oil accumulations sharing similar geologic, geographic, and temporal properties, such as source rock, migration pathway, timing, trapping mechanism, and hydrocarbon type.

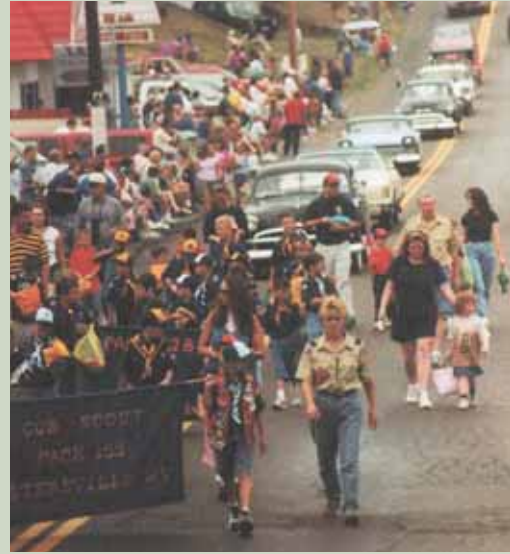
Top 3 misconceptions about the Appalachian and Illinois basins

3. Oil and gas in the basins have little impact on jobs or economic growth.
2. The basins are played out and are not attractive for investment.
1. The basins are no longer important to the nation's energy future.

Birthplace of the nation's natural gas production

The discovery of natural gas in the United States was an accident. Appalachian salt miners struck oil instead of salt in Ohio in 1814, and gas instead of salt a year later in West Virginia. The first intentional attempt to find natural gas occurred in 1821 near Fredonia, New York, drilling to a depth of 70 feet. Fredonia gas was sold to nearby hotels and businesses, and lit local streetlamps. In the years that followed, new uses were found for the natural gas so readily produced from the ground. Natural gas became a desirable fuel for evaporating the brines in the process of salt-making, since oil ruined the quality of the brine and produced salt. Natural gas was also used to dry grain on farms and to fuel steam production plants and steel furnaces. Soon gas was discovered in Pennsylvania (1860), Ohio (1861), and Kentucky (1863). Availability of natural gas in Indiana in the 1880s formed the basis for new industries like glassmaking in the aptly named Gas City.

During this period of American societal and economic growth, the Appalachian and Illinois basins fed a steady stream of gas to the energy-hungry nation. From the late 1880s to 1930, the Trenton field in Ohio and Indiana achieved total production of more than 1.5 Tcf of natural gas.



The annual West Virginia Oil and Gas Festival in Sistersville celebrates the inventive, colorful history of petroleum production in the Appalachian basin.

Home of America's oldest oil wells

The modern oil industry evolved in response to the nation's need to find new ways to keep its lamps lit. At the time, lamp oil was produced from whales in a laborious, expensive, and inhumane process. But a New York lawyer, George H. Bissell, saw potential in "rock oil," a byproduct of salt mining. Bissell purchased a farm in northwestern Pennsylvania and formed an unsuccessful company for surface oil recovery. It wasn't until he met Edwin L. Drake and salt driller "Uncle Billy" Smith that the three decided to try collecting oil by drilling into the Pennsylvania earth.

In 1859 they struck oil at a depth of almost 70 feet, just south of Titusville. They were so far ahead of their time that technology was just being invented to refine what they were withdrawing from the ground. Just 10 years later, 1,186 oil-producing wells had been drilled in the area, and Pennsylvania became the center of the world oil industry. Other states in the region soon began producing oil as well: West Virginia (also in 1859), New York (1865), Kentucky (1865), Ohio (1884), Indiana (1886), and Illinois (1904).



It took a particular kind of individual to work the oil fields, like the "roughnecks" seen above. Below, oil wells dot the landscape in Richburg, New York, in 1883; oil production peaked in the state at 6.5 million barrels a year earlier.

The basins remain rich in undiscovered and “unconventional” resources

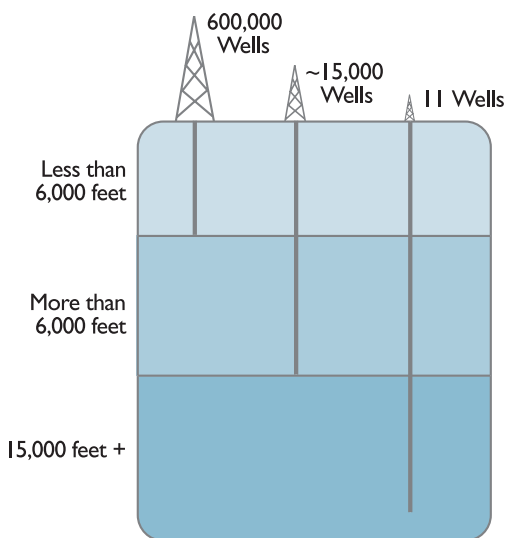
How much of the substantial oil and natural gas resources in the Appalachian and Illinois basins can be recovered economically and with what levels of investment? Making informed estimates requires an understanding of the different categories of resources in the basins and the unique challenges of exploring and producing them.

The resource pyramids on page 7 provide a way to visualize potentially recoverable oil and natural gas in the basins. The hydrocarbons are categorized as layers of successively lower quality, less accessible, more costly, and/or more uncertain resources. The volume of potential resource in each category tends to increase as one moves down the pyramids. As technology and understanding of resources advance, the lower quality, higher cost, more uncertain resources can become more accessible and economical, enabling them to make a larger contribution to future oil and gas supplies.

“Unconventional” natural gas represents, by far, the largest category of estimated remaining hydrocarbon resources in the Appalachian and Illinois basins. Compared to conventional resources, unconventional gas deposits are found in more complex geological settings and often require newer development methods to overcome the limits of traditional production processes. Today, the newer development methods required to produce unconventional gas resources are increasingly being applied. Indeed, approximately two-thirds of the successful gas wells currently drilled annually in the United States are drilled into unconventional settings.

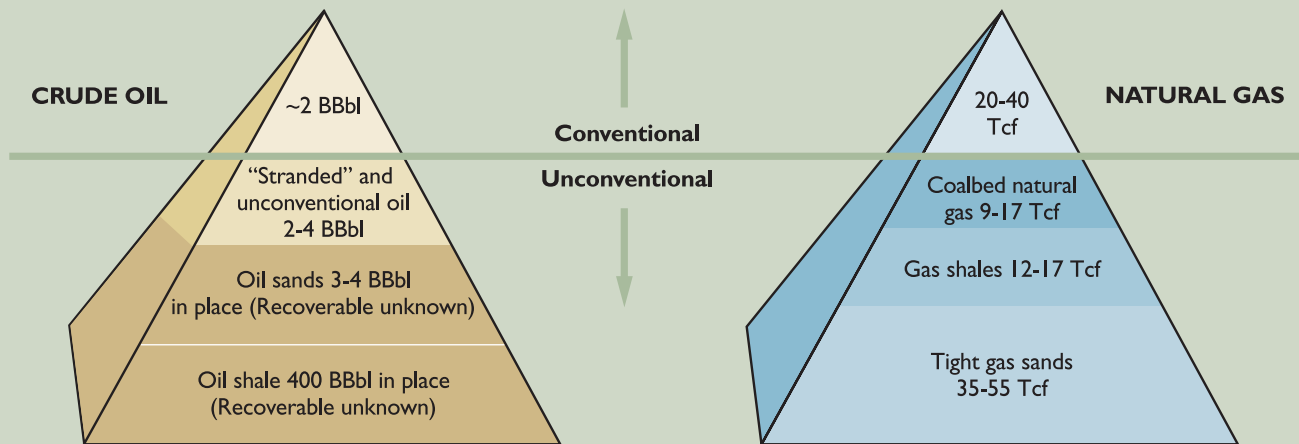
Advances in drilling that allow resources to be identified and produced with lower cost and risk may prove to be particularly valuable in these basins. One promising avenue is directional or horizontal drilling. These technologies allow operators to reach reservoirs up to several miles from the drilling site, so that more resources can be recovered with fewer wells, less waste, and less surface disturbance.

Deep drilling is another technology that can change the face of production in the Appalachian and Illinois basins. Although nearly 600,000 wells have been drilled in these basins over the last century and a half, only a small portion have been drilled deeper than 6,000 feet, leaving potential resources at even greater depths virtually unexplored. The Potential Gas Committee (PGC) estimates that about 10 percent of the undiscovered natural gas resource in the Appalachian basin is deeper than 15,000 feet, representing about 6 Tcf, and it is reasonable to speculate based on regional geology that substantially greater volumes could exist in deeper horizons. With new technologies that reduce the costs and risks of deep drilling, these untapped resources may now be within economic reach of producers.



New frontiers in deep gas
Even though the Appalachian and Illinois basins are mature in terms of shallow production (less than 6,000 feet), they are considered rather young in terms of deeper exploration (more than 15,000 feet). Indeed, according to the Potential Gas Committee, only 10 to 15 percent of the possible hydrocarbon-producing formations within the Appalachian basin have been tested, and only 11 wells have been drilled deeper than 15,000 feet in the basin.² Most wells have been concentrated along established producing trends, and vast areas remain unassessed.

Oil and natural gas technically recoverable resources in the Appalachian and Illinois basins*



CONVENTIONAL RESOURCE ESTIMATES

An estimated 2 BBbl of conventional crude oil remains in the basins, including:

- **Proved reserves.** As of the end of 2003, nearly 0.4 BBbl of proved, producing crude oil and natural gas liquids reserves had been booked in the basins.³
- **Probable/Inferred reserves.** The USGS estimates that there are more than 1.2 BBbl of inferred crude oil and natural gas liquids reserves in the "Eastern Region"⁴ of the United States.
- **Undiscovered resources.** The USGS mean estimates for technically recoverable undiscovered crude oil and natural gas liquids resources in the Appalachian and Illinois basins are nearly 0.4 BBbl, with more than 70 percent in the Illinois basin. This amount is comparable to current proved oil reserves in the two basins.⁵

UNCONVENTIONAL RESOURCE ESTIMATES

Stranded oil resources remain in the ground after traditional primary and secondary oil recovery and can often represent two-thirds of the original resource in place. From 1 to 2 BBbl of stranded oil exists in the basins. Another 2.4 BBbl of liquids is believed to be associated with remaining unconventional gas resources.

PROSPECTIVE FUTURE RESOURCES

Two additional categories of prospective future resources exist in the basins, although the technically recoverable portion of these resources has not been estimated.

- **Oil sands** contain bitumen⁶, the recovery of which requires mining or heating the reservoir. An estimated 3 to 4 BBbl in place of oil sands exist in the Appalachian basin, primarily in Kentucky. With today's technology, little of this resource is economical to recover, but with improved technologies some could be recoverable in the future.⁷
- **Oil shale** refers to kerogen, a hydrocarbon contained in hard rock that requires processing similar to that for oil sands. Resources of oil shale in the eastern United States may exceed 400 BBbl⁸ in place, although the quality of these shales is quite inferior to shales in the West. None of this resource approaches economic viability with today's technology but could represent a future target.

CONVENTIONAL RESOURCE ESTIMATES

An estimated 20 to 40 Tcf of "conventional" natural gas remains in the basins, including:

- **Proved reserves.** As of the end of 2003, 11 Tcf of natural gas reserves had been booked in the Appalachian and Illinois basins.
- **Probable/Inferred reserves.** The USGS estimates that there are 3.7 Tcf of inferred natural gas reserves in the "Eastern Region" of the United States. In contrast, the PGC estimates that probable natural gas resources in Appalachian and Illinois basins are on the order of 20 Tcf, while the National Petroleum Council estimates potential reserves growth in its Eastern Region to be on the order of 5 Tcf.⁹
- **Undiscovered resources.** The USGS mean estimate for undiscovered conventional natural gas resources for the two basins is estimated to be 4.8 Tcf, with the vast majority in the Appalachian basin. This represents about 50 percent of current proved reserves in the two basins.

UNCONVENTIONAL RESOURCE ESTIMATES

Unconventional natural gas resources have been produced throughout the oil and gas development history in these basins, though their full potential is far from being realized. With today's technologies and improving market conditions, production of these resources — including gas in "tight" sandstones, gas shales, coalbed gas, and other continuous-type deposits — is becoming more attractive. Unconventional resources represent, by far, the largest proportion of the natural gas resource remaining in the basins, amounting to 61 to 76 Tcf of technically recoverable natural gas (see table on page 9).

Definitions

"Proved reserves" are demonstrated with reasonable certainty — based on geologic evidence — to be profitably recoverable in the future from known reservoirs.

"Probable/Inferred reserves" (reserve growth) are assumed to be recoverable with additional development of discovered fields.

"Undiscovered conventional resources" are postulated to exist outside of known oil and/or gas fields based on geologic information and theory, and are contained in discrete accumulations from which oil and/or gas can be extracted using traditional development practices.

*Note: Resource categorizations here expand upon those shown in the table on page 9. Included here are new resource categories (stranded oil, oil sands, and oil shale) not included in the table.

Challenges of estimating oil and natural gas resources

Oil and natural gas resource estimates change continually in response to advances in geologic knowledge, exploration and recovery technology, and the economic and policy conditions under which exploration and production are expected to occur. Accurate and timely assessments of the nation's potential resources are essential to ensure that public policy is based on sound information.

Estimates of resources in the Appalachian and Illinois basins are particularly uncertain. One factor contributing to the uncertainty is the limited availability of data on past production and on the characteristics of prospective plays. A second unknown is the potential impact of technology progress. Resource assessments typically assume that only current technology, or incremental improvements on that technology, will be available to recover resources. Throughout the history of these basins, technological leaps have helped industry to pursue resources previously thought unproductive or have helped to reduce exploration and production costs, creating large and unexpected additions to recoverable resources.

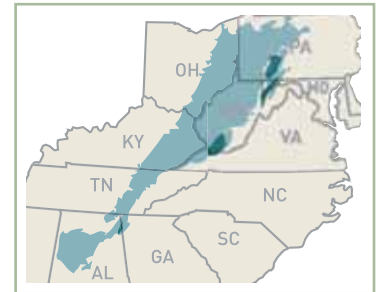
See the table on page 9 for a range of current resource estimates for the Appalachian and Illinois basins.

Several plays are attracting new interest in the basins

Most of the plays generating renewed interest in the Appalachian and Illinois basins are in challenging geological formations – including coal seams, tight gas sands, and gas shales – or in deep horizons. Several specific plays of interest are profiled below.

Coalbed natural gas

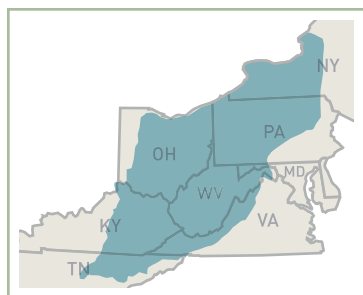
Coalbed natural gas is a plentiful resource throughout both the Appalachian and Illinois basins that has attracted renewed attention in the last decade. Coal production has been established here for more than a century, with both shallow and deep coal deposits distributed extensively throughout both basins. Since the late 1970s, thousands



of coalbed natural gas wells have been drilled in these basins. Today, advances in horizontal drilling, completion, and production technology make it increasingly possible to pursue coalbed natural gas as a separate product. For example, coalbed natural gas from approximately 1,200 acres can be produced using horizontal and pinnate drilling technology from only 2 or 3 surface wells, in contrast to the 50 conventional vertical wells that would have been required with previous technology. Advances in water handling and treatment systems also make coalbed gas production economic today in areas that could not have been developed just 10 years ago.

Penn Virginia Oil and Gas Corporation is using horizontal well and pinnate drilling technology to add more than 300 Bcf of reserves in West Virginia. Horizontal/Multilateral pinnate completion technology, pioneered by CDX Gas LLC, is being applied as an alternative to conventional hydraulic fracturing to stimulate production from low-permeability continuous reservoirs like coals (and in the future, perhaps, also gas shales). The company has added reserves at an annual growth rate of 25 percent consistently over the last five years – in a basin many believed to be mature with limited potential. In their core areas, a typical well produces from 150 to 200 Mcf per day. Horizontal wells, while costing four times more than traditional vertical wells in this area, can produce gas at 10 times the rate of vertical wells.¹⁰

Trenton/Black River



The deep Trenton/Black River play extends through parts of New York, West Virginia, Ohio, Kentucky, Tennessee, Pennsylvania, and Ontario, Canada. A multistate study is under way to assess the geologic extent and exploratory potential of this play across the Appalachian and Illinois basins.¹¹

Recent discoveries have generated renewed interest in the oil and natural gas potential of this play in the Appalachian basin. Commercial production requires an ability to detect fractures that could enhance matrix permeability and serve as flow pathways. Advanced geophysical analyses, including 3D seismic data acquisition, attribute analyses, new logging techniques, and seismic modeling, coupled with integrated models incorporating all available geologic and geophysical data, are helping to identify the most promising prospects in this play.

Fortuna Energy, a wholly owned subsidiary of Canadian-based Talisman Energy, has brought its track record in horizontal drilling and in the Trenton/Black River north of the border to the Finger Lakes region of New York. The first two wells completed by Fortuna tested at 2.4 MMcf per day and 10.4 MMcf per day.¹² Another well drilled to a depth of 10,100 feet tested in excess of 18 MMcf per day. Some wells drilled into this trend are, in fact, among the highest producing in the eastern United States. A well drilled by Columbia Natural Resources LLC in West Virginia in 1999 flowed 50 MMcf per day¹³, and another drilled in the Finger Lakes region located reserves estimated at 20 Bcf.¹⁴ In 2000, a well drilled by Pennsylvania General Energy Corporation in Steuben County, New York, produced at an average rate of nearly 3 MMcf per day its first year. More recently, Fortuna drilled a vertical well – which was then steered horizontally – to a depth of 12,050 feet that tested at a choked rate of 19 MMcf/day. The well was brought on stream at a rate of 34 MMcf/day and had produced 5.3 Bcf by November 2004.¹⁵



Through year-end 2004, New York's Trenton/Black River wells produced more than 110 Bcf of natural gas.

Various Estimates of Technically Recoverable Resources in the Appalachian and Illinois Basins

	Crude Oil & Natural Gas Liquids (BBbl)		Natural Gas (Tcf)		
	U.S. Geological Survey (USGS)	U.S. Geological Survey (USGS)	Potential Gas Committee (PGC)	National Petroleum Council (NPC)	Advanced Resources International (ARI)
Proved reserves (1)	0.400	10.9	10.9	14.0	*
Probable/Inferred (2)	1.200	3.7	19.8	5.0	*
Undiscovered conventional (3)	0.353	4.8	*	15.0	*
Unconventional coalbed	-	10.0	16.8	9.8	9.1
Tight gas sands (3)	2.737	45.5	31.2	34.7	55.2
Gas shales (3)	0.096	15.4	*	17.0	12.0
Unconventional subtotal	2.833	70.9	48.0	61.5	76.3
Total remaining resources	4.786	90.3	78.7	95.5	-

1 Proved reserves for oil include Illinois, Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia. For gas, estimates include Kentucky, New York, Ohio, Pennsylvania, Virginia, and West Virginia.

2 USGS and NPC estimates for inferred reserves are for Eastern Interior, which includes the Appalachian and Illinois basins, and the Michigan and Black Warrior basins.

3 PGC estimates for conventional also include primarily tight gas and gas shales.

* Not estimated separately.

Pinnacle reefs

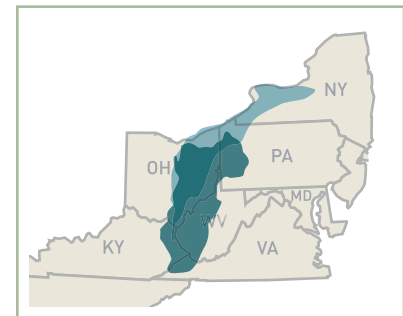
Pinnacle reefs also hold potential in the Appalachian and Illinois basins. Coral reefs that grew in warm shallow seas and were buried over time provided formations within which hydrocarbons could accumulate. Approximately 80 pinnacle reefs have been discovered in the Illinois basin in Indiana and Illinois. Some of the reservoir structures were formations overlying the actual reef rock, while in other cases, the reef rock itself is the reservoir.



Many of these reservoirs have been found by chance – traditional efforts to establish methods to predict the trend in these reefs were often not successful. More recently, improved technology and more systematic, stratigraphic test well programs are resulting in more success. An exploration well drilled in Marion County, Illinois, by Tulsa-based Ceja Corporation found a pinnacle reef that may be the largest modern oil field in Illinois. This deep structure underlies the Miletus field and was identified by reprocessing old seismic data with new technologies. Ceja deepened an existing well to test the reef, and the well produced 70 barrels per day. Ultimate reserves resulting from delineation drilling are now estimated to be 5 to 6 million barrels.¹⁶ Recent approvals by the Illinois Department of Natural Resources to apply seismic imaging along an abandoned pipeline right-of-way in the Stephen A. Forbes State Park, just south of the Miletus discovery, where access had previously been denied, may help in the discovery of similar fields.

Tight gas sands

Although believed to be quite mature, tight gas sands in the Appalachian basin remain a potentially substantial source of future gas supplies. More than 9 Tcf have been produced to date from more than 75,000 wells in this basin, the birthplace of U.S. tight gas production. Future reserves are estimated to be on the order of 3 Tcf. Tight gas plays primarily include the Clinton/Medina, Berea, and Oriskany. Most of the current drilling in Pennsylvania and West Virginia is targeting tight gas formations. These plays are now being targeted by several companies. For example, Range Resources Corporation is accelerating its shallow tight sand development program in Appalachia in 2005 with 48 wells planned for the year.



Shale gas

The New Albany Shale and other Devonian shales are other resources that are sparking renewed interest. Since the early 1860s, more than 600 wells have been drilled into the New Albany Shale in Indiana and Kentucky. Recent success in the Antrim shales of the Michigan basin may bode well for renewed production in the New Albany, whose characteristics are very similar. With as much as 1.9 Tcf of technically recoverable reserves estimated to exist in the New Albany¹⁷, several companies are now consolidating large lease blocks or obtaining permits to produce gas from this play. Companies successfully drilling New Albany wells in Kentucky include Inexco Oil Company (Butler County) and Endeavor Energy Resources LP (Breckinridge County), with Quicksilver Resources (Meade County) and El Paso Production Co. (Davies County) having success in Indiana.^{18, 19}

Production from the New Albany Shale depends on the number of fractures encountered by a well bore or through stimulation or artificial fracturing. Technologies to verify fracture geometry and intersect multiple fractures using horizontal drilling or hydraulic stimulation will have a significant impact on the viability and productivity of the shale. One barrier to New Albany gas production lies in the shortage of infrastructure for gathering, compression, and processing to move the resources to market through the interstate gas transmission network. Although Indiana has a substantial interstate pipeline system, the availability of feeder system pipelines to carry New Albany gas is limited. To date, the largest production from New Albany has occurred in an area where a single end user was willing to pipe the gas from a field to their facility.

Oil sands and oil shale

Heavy oil, oil sands, and oil shale are also large resources in the Appalachian basin that could add to domestic supplies in the longer term. For example, 3 to 4 BBbl of oil in place exists in oil sands, primarily in Kentucky. The adaptation of new technologies being tested in Canada, such as SAGD (steam assisted gravity drainage), VAPEX (the use of a combination of solvent and heat), and the “top down combustion” process, could help unlock the potential of oil sands. Another new technology being developed uses down-hole heating elements and “ice” barriers to potentially produce oil from oil shale in an economical and environmentally acceptable manner.²⁰



After drilling, the site is reclaimed, and the well head and fluid separation and/or compression equipment may be all that remain in the rural landscape.

Eastern states benefit significantly from natural gas and oil production

Oil and natural gas production from the Appalachian and Illinois basins not only makes important contributions to the nation’s domestic energy portfolio; it also creates significant positive impacts on the regional economies of Eastern states.

One of the obvious benefits is **job creation**, which occurs all along the oil and natural gas “value chain” – from exploration and production, to oil refining and gas processing, to transportation and storage, all the way through to oil and gas distribution and retailing.

Other benefits include the **direct expenditures** associated with oil and gas industry activity and the **revenues** state governments collect from severance and corporate income taxes on oil and gas

production. In 2003 the Appalachian and Illinois basins states received approximately \$35 million in state production taxes. Oil and gas activities on state lands yield additional revenues. For example, from 1947 to 2002, receipts to the state of Pennsylvania from leases for gas storage and oil and gas production amounted to more than \$133 million.²¹

Less obvious are the **indirect economic benefits to businesses and consumers** of regionally produced energy, particularly natural gas. For every million dollars invested in oil and gas development, about three direct industry jobs are created or sustained, with another three to four indirect jobs per direct job. Moreover, almost every industry, business, and homeowner uses natural gas these days, and natural gas is increasingly used for power generation in the region. These markets depend on reliable supplies at a time when domestic natural gas production is not keeping pace with demand. According to the Energy Information Administration (EIA), consumption of natural gas in the United States will increase to more than 30 Tcf annually by 2025, but domestic production will increase only slightly to approximately 22 Tcf annually. As the discrepancy between domestic supply and demand grows, gas produced in the Appalachian and Illinois basins will make an ever-more-vital contribution to the economies of Eastern states.



Pittsburgh is among the large population and industrial centers in the Appalachian and Illinois basins. These centers consume a much higher percentage of natural gas than they produce.

Oil and Natural Gas in the Appalachian and Illinois basins states²²

	Production					Employment				
	Active Wells (2004)		Annual Production (2004)		Market Value (2004)	Total Jobs	Oil/Gas Extraction	Refining	Transportation	Wholesale & Retail
	Oil	Gas	Oil (Thousand Bbl)	Gas (MMcf)	(\$ Million)					
Illinois	31,860	240	11,696	126	\$450	45,678	2,111	7,110	6,120	30,337
Indiana	5,385	919	1,755	3,401	\$91	32,663	391	452	3,346	28,474
Kentucky	28,265	15,764	2,548	94,292	\$764	27,596	1,581	1,101	2,005	22,909
Maryland	0	7	0	48	<\$1	15,998	161	0	804	15,033
New York	2,872	6,045	175	46,923	\$338	50,399	964	820	4,338	44,277
Ohio	29,039	33,828	5,785	90,301	\$860	48,954	4,660	2,134	4,969	37,191
Pennsylvania	16,061	43,906	3,670	163,300	\$1,295	60,698	3,853	5,097	7,798	43,950
Tennessee	510	350	350	1,000	\$21	31,659	526	624	1,093	29,416
Virginia	7	4,673	21	85,800	\$608	41,962	956	331	2,220	38,455
West Virginia	3,937	43,034	1,474	201,770	\$1,483	17,528	4,013	871	2,770	9,874
TOTALS	117,936	148,766	27,474	686,961	\$5,911	373,135	19,216	18,540	35,463	299,916

Economic benefits are substantial across the oil and natural gas value chain

More than 370,000 people are employed in the oil and natural gas industry in the Appalachian and Illinois basin states, from exploration and production through wholesaling and retailing.²³ Regional industries employing millions more workers rely on oil and natural gas for feedstocks or process heat – particularly primary manufacturing and materials industries that, in turn, have a profound impact on the U.S. economy as a whole.

Helping to Meet Peak Demand



Exploration & Production

Appalachian and Illinois basins account for more than 19,000 direct jobs in exploration and production.



Refining & Processing

About 18% of the nation's crude oil refining capacity exists in the Appalachian and Illinois basin states.²⁴



Transportation & Storage

An extensive network of pipelines and storage fields connects producers in the region with important markets. More than 40% of the nation's natural gas storage capacity exists in Appalachian and Illinois basin states.²⁵



Wholesale & Retail Distribution

A vast network distributes natural gas and petroleum products throughout the Appalachian and Illinois basins states, which constitute the most densely populated region of the country.



End Uses

Oil and natural gas produced in the Appalachian and Illinois basins find ready markets in the region as fuels and feedstocks in the commercial, industrial, residential, transportation, and agricultural sectors. Natural gas is also increasingly used to fuel power plants.

Consumption

Oil Consumption Percent of State Energy Use by Sector							Natural Gas Consumption Percent of State Energy Use by Sector						
Total	Resid.	Comm.	Ind.	Elec. Pwr	Transp.	Total	Resid.	Comm.	Ind.	Elec. Pwr	Transp.		
34%	2%	2%	28%	1%	98%	25%	47%	23%	24%	3%	1%	Illinois	
30%	4%	3%	16%	<1%	99%	18%	30%	20%	20%	1%	1%	Indiana	
37%	3%	3%	30%	<1%	97%	12%	17%	15%	12%	<1%	3%	Kentucky	
40%	9%	5%	31%	7%	99%	13%	20%	17%	11%	4%	1%	Maryland	
41%	20%	12%	31%	12%	96%	29%	33%	28%	13%	24%	1%	New York	
33%	4%	2%	20%	<1%	98%	21%	36%	26%	21%	1%	2%	Ohio	
37%	16%	6%	20%	2%	96%	17%	27%	20%	17%	1%	4%	Pennsylvania	
32%	2%	2%	16%	1%	98%	12%	14%	15%	16%	<1%	2%	Tennessee	
39%	9%	4%	20%	7%	99%	11%	13%	12%	13%	5%	1%	Virginia	
28%	5%	3%	16%	<1%	82%	20%	23%	27%	17%	<1%	18%	West Virginia	

Independents make vital energy contributions

The oil and gas industry is frequently characterized as Big Oil. Yet this image is misleading. Thousands of independent oil and gas producers – most employing fewer than 20 people – drill 85 percent of the nation's wells and produce 65 percent of the natural gas and nearly 40 percent of the oil produced in the United States. Recognizing the important contributions of these producers to our nation's domestic energy portfolio, the U.S. Department of Energy has technology transfer programs targeted specifically to small independents.

Small producers are single-handedly responsible for maintaining the operation of "stripper" wells in the United States, defined as a gas well that produces less than 60 thousand cubic feet (Mcf) of gas per day, or an oil well that produces less than 10 barrels (Bbl) of oil per day. In 2003 there were 260,563 stripper gas wells in the United States, producing a total of 1,478 Bcf, or enough to meet one month of U.S. natural gas demand. That same year, there were 393,463 stripper oil wells²⁶, producing a total of 313 MMBbl, which was 15 percent of total oil produced in the lower 48 states.



Small businesses are the backbone of the Appalachian and Illinois basins

Small independent oil and gas producers and service companies predominate in the Appalachian and Illinois basins. During the past 10 years, thousands of independent operators have been in business in the basin states²⁷, with the greatest numbers in Pennsylvania, Ohio, West Virginia, and Kentucky. Many operators are small family-owned businesses that are vital economically to their rural communities. Because these small businesses have limited capital, many find it difficult to invest in large or deep drilling projects, or to apply state-of-the-art technologies. Their next year's drilling schedule often is determined by this year's revenues, and is weighed against uncertain and volatile oil and natural gas prices.

Producing natural gas wells in the Appalachian and Illinois basins numbered 148,766, approximately 38 percent of the over 393,000 producing gas wells in the United States, according to the Energy Information Administration. Moreover, 117,936 of the nation's 520,000 producing oil wells (23 percent) are also in this region. Many of these wells are low-volume "stripper" wells. Cumulatively, stripper well oil and natural gas production is an important supply source for the Appalachian and Illinois basin states and for the country as a whole.



Beside his service rig truck, Carl D. Perkins of Pennsboro, West Virginia, stands with son Deryl and grandsons Clay and Clint. Carl Perkins is president of Perkins Oil & Gas, Inc., an independent producer.

Prerequisites for Bringing Resources to Market

Keys to reinvigorating production in the basins

Realizing more of the oil and natural gas resource potential of the Appalachian and Illinois basins will take action on several fronts. Investments in technology will be needed for maintaining production in marginal fields and for applying new technologies, like CO₂-based enhanced oil recovery, in mature fields in the Appalachian and Illinois basins.

In addition, supportive policies will be needed to provide appropriate access to resources, enable necessary infrastructure expansion, enhance access to high-quality information on resource potential, and ensure environmental stewardship. Each of these prerequisites is discussed on the following pages.

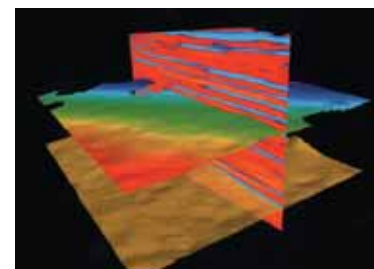
Prerequisite 1: Technology progress

Production of oil and natural gas in the Appalachian and Illinois basins was concentrated in the late 19th and early 20th centuries, in an era when technology options were limited. A host of recent technology advances have been underutilized in the basins to date, but could greatly enhance the region's oil and natural gas recovery potential. Increased development and application of advanced technology will be essential to meet the challenges of producing the unconventional and challenging resources that constitute most of the remaining potential in the basins.

Extending well life

Perhaps the most immediate target for advanced technologies is **extending the lives of marginally economical wells**. Production levels in many wells decline prematurely and unnaturally, often due to avoidable and repairable wellbore damage; higher oil and natural gas prices alone are

not enough to save wells – and entire fields – from premature abandonment. To assist the small and independent operators who own the vast majority of the nation's stripper wells, The Pennsylvania State University, with support from the U.S. Department of Energy and New York State Energy Research and Development Authority (NYSERDA), established the Stripper Well Consortium. Through the consortium, operators leverage their resources to analyze the causes of premature production decline and to develop effective remediation approaches. Such efforts can result in higher production volumes, longer well life, and, thus, greater cumulative production. An example of a developing technology suitable to the Appalachian and Illinois basins is a “gas operated automatic lift pump” that can reduce lifting costs and increase production.



This seismic image shows subsurface features including petroleum reserves. Use of 3D imaging increases the likelihood of success in targeting oil and gas resources.

Exploration

Other technologies will enable the economical development of new wells. For example, **improved fracture detection** will enable developers to better assess the producibility of natural gas from tight sands, coal seams, and shales. Exploration technology to verify the geometry of fractures, coupled with the creation of maximum fracture intersection through techniques such as horizontal drilling, will have a significant impact on the overall ability to produce gas economically from these formations. Research to improve natural fracture prediction for tight gas sands is currently being conducted in other tight gas basins with results that may benefit operators in the



The location of the drill site may vary based on geology, topography, surface access, and other factors, as illustrated by this high-elevation site in Virginia.

Appalachian and Illinois basins. Another development with potential applicability in the basins is taking place in the Fort Worth basin, where horizontal wells are being used successfully to intersect open fractures in the Barnett Shale. Although horizontal wells have been drilled in the past, success in the Barnett may stimulate renewed interest in drilling horizontal wells in gas shales in the Appalachian and Illinois basins.

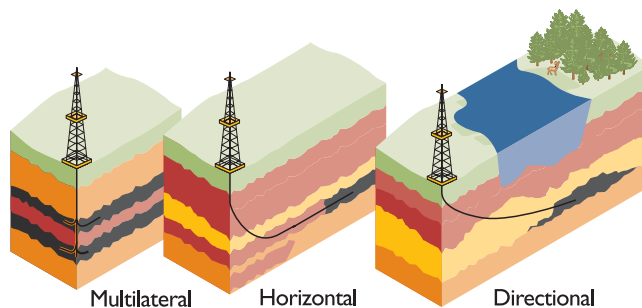
Another exploration technology that can be beneficially applied in the basins is **advanced 3D seismic imaging**. Widely used in oil and gas fields throughout the world, 3D seismic imaging provides developers with detailed information about fault distribution and subsurface structures. Increasingly, operators in the Appalachian and Illinois basins are finding economic justification for purchasing 3D seismic data to refine their stratigraphic objective in complex reservoirs, including deep targets and reef plays. Further advances in processing, seismic modeling, and attribute analyses will help better identify current and new targets for exploration in the Appalachian and Illinois basins.

Drilling and completion

Advances in **drilling and completion** technologies clearly will be important in decreasing future well costs and making more resources economically producible. “Tight gas sand” stimulation techniques may be particularly applicable within the Appalachian basin, enabling operators to improve gas production rates. Other key advances are horizontal and lateral sidetracks. Horizontal and lateral drilling has already proved valuable in the region – for example, by enabling operators to drill successfully in the Trenton/Black River reservoirs in New York. Drilling and completion techniques also are needed to address the challenges of unexplored deep reservoirs in the basins. Technologies currently under development by DOE’s Deep Trek program include high-temperature electronics for wireline tools applied under conditions greater than 15,000 feet and 400 degrees Fahrenheit, and deep sand completion techniques. These advancements could one day help make exploration and production of deep gas reservoirs in the Appalachian basin economically feasible.

Production

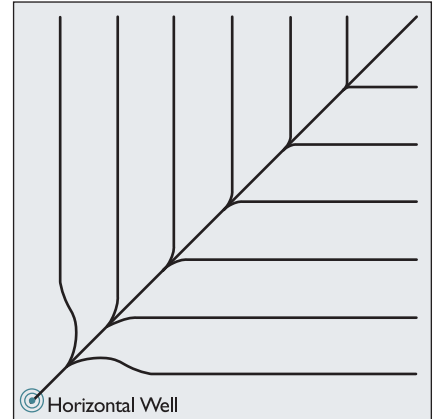
Technologies specific to **coalbed natural gas production** are being applied increasingly in basins across the United States, and hold promise for enhancing production from the Appalachian and Illinois basins. Examples include advances in multi-seam drilling and completion of thin or low-permeability coals, retreatment of existing wells, and efficient drilling and completion of lower-gas-content



Multilateral, horizontal, and directional drilling technologies enable more resources to be recovered with less waste and surface disturbance.

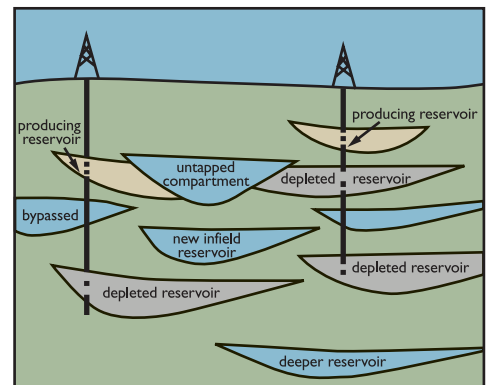
coals. One technology that has been applied successfully in southern West Virginia is the CDX Z-PINNATE™ drilling and completion system. This technique uses a multilateral horizontal network (resembling the shape of a leaf) that can drain 1,200 acres of coal with one well, far exceeding the 80- to 100-acre capability of existing technologies.

Potentially “stranded” natural gas and oil resources in depleted fields in the basins can be pursued with advances in **enhanced recovery techniques**. Anywhere from 50 to 70 percent of oil and 20 to 30 percent of natural gas is not recovered with traditional approaches. Broader use of enhanced recovery technologies (CO₂ flooding, steam flooding, or water flooding) with 4D seismic imaging and automated field monitoring may enable recovery of more of the original oil-in-place after primary production is completed in oil fields. According to the *Oil and Gas Journal*, CO₂ flooding is the fastest growing form of enhanced oil recovery in the United States, producing an estimated 206,000 barrels per day in 2004²⁸, mostly in the Permian basin of West Texas and New Mexico. To date, this technique has seldom been attempted in the Appalachian and Illinois basins. However, experience in the Permian basin and the Weyburn field in Saskatchewan, Canada, could provide a model, helping to overcome the risks and economic barriers associated with applying this technology to recover stranded oil in other basins, such as the Illinois and Appalachian basins. Other ways to encourage use of this technology to recover stranded oil in the basins include conducting research, pilot tests, and field demonstrations; providing risk-mitigating packages, such as state production tax incentives, federal investment tax credits, and royalty relief; and establishing low-cost, reliable CO₂ supplies from natural and industrial sources. In the near term, sources could include high-concentration CO₂ emissions from refinery hydrogen plants and gas processing facilities. Capture of lower-concentration emissions from sources such as electric power generation plants could be feasible in the longer term. Capturing CO₂ emissions for use in enhanced oil recovery also could have synergy with state, regional, and nation objectives to reduce atmospheric concentrations of greenhouse gases.²⁹

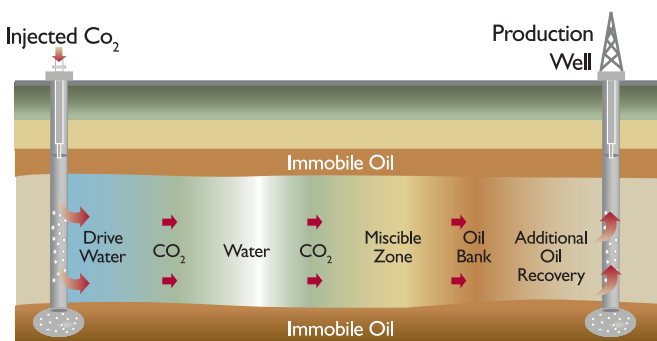


Z-PINNATE™ System Pattern

One example of a horizontal drilling pattern applied in coalbed natural gas production is the CDX Z-PINNATE™ drilling and completion system, which allows operators to produce more gas with fewer wells, in turn reducing stresses on the environment.



Much of the underdeveloped hydrocarbon resource in the Appalachian and Illinois basins exists in reservoirs that were difficult to find and access with traditional technologies. With advanced technologies such as 3D seismic and horizontal/directional drilling, these prospects can now be pursued.



A recent study found that 43 billion barrels of stranded oil could be recovered using available state-of-the-art carbon dioxide-enhanced oil recovery (CO₂-EOR) techniques in six U.S. basins. Of that, nearly one billion barrels are located within 46 reservoirs in Illinois.³⁰

Unique state actions in Virginia to increase energy supplies

A bill passed overwhelmingly by the Virginia state legislature in 2005 directed state officials to ask Virginia's congressional delegation to advocate an exemption to the federal moratorium on offshore natural gas exploration. Virginia would have become the first state to formally seek an exemption from the federal moratorium Congress enacted in 1982 that prohibits offshore drilling on the Atlantic and Pacific coasts and part of the Gulf of Mexico. This bill, however, was later vetoed by the governor in part because it directed the state to advocate for federal legislation that had not yet been introduced. Legislation subsequently introduced in the 109th Congress would give coastal state governors the power to open some or all of their states' offshore lands restricted by federal moratoria, with an emphasis on "gas-only" leasing.

On another front, Virginia succeeded in encouraging coalbed gas production through legislative action. Decades of mining in the southwest Virginia coalfields had demonstrated the gassy nature of coals in the area. Development of the gas as a separate product, however, had been stymied by split mineral estates: coal owners and oil and gas owners, each of whom claimed ownership of the coalbed gas, were often separate entities. To address the ownership dilemma, the Virginia legislature passed landmark legislation in 1990 that provided for compulsory pooling of unleased parties and the escrow of proceeds due to conflicting claimants to coalbed gas. This action allowed development to go forward while protecting the interests of claimants until ownership could be determined through court order or agreement. As a result of the legislation, gas production in Virginia's seven-county producing area has increased more than 400 percent and continues to rise. Coalbed gas currently makes up nearly 80 percent of Virginia's total yearly gas production.

Technology transfer

Across the board – from exploration, to drilling and completion, to production – advanced technologies can make all the difference in enabling increased energy supplies from the Appalachian and Illinois basins. Unfortunately, the application of advanced technologies in this region is not yet widespread, and smaller independent producers, who account for the majority of oil and natural gas production in the basin states, often lack the access to capital and expertise required to integrate advanced technologies into their operations. Substantially greater efforts are required to further demonstrate the potential applicability of advanced technologies to independent producers in the Appalachian and Illinois basins. This would build upon efforts currently ongoing, primarily conducted by the IOGCC and the Petroleum Technology Transfer Council, an industry-driven, nationwide organization. West Virginia University serves as the regional lead organization for the Appalachian region, and the Illinois State Geological Survey is the regional lead organization in the Illinois and Michigan basins.

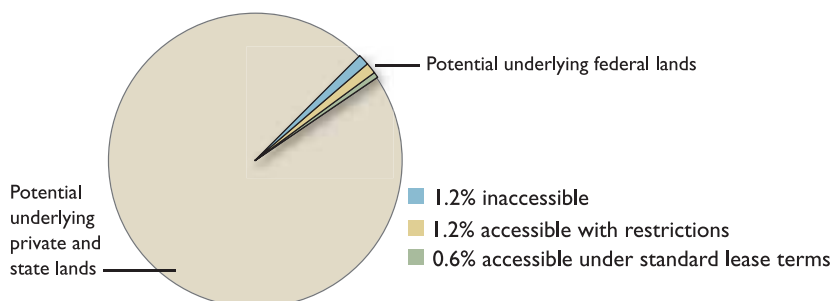
Prerequisite 2: Access to resources

Obtaining access to oil and natural gas resources can be complex, involving the interests of private land and royalty owners, ambiguous mineral rights, and competing land uses. Unlike in the western United States, where a significant portion of undeveloped resources underlie public (primarily federal) lands and are either unavailable for leasing or subject to additional leasing restrictions, most of the resource base in the Appalachian and Illinois basins is held by rights with private entities. Nevertheless, much of the area with future potential still faces access issues.

Federal lands

About five percent of total acreage in the Appalachian basin (more than five million acres) is on federal lands or on split-estate lands where the federal government owns mineral rights while another entity owns the surface land. Federal lands in the basin are managed primarily by the U.S. Forest Service. Only about three percent of the undiscovered resource

Very little of the undiscovered oil and natural gas resources in the Appalachian basin are on federal lands.



potential in the basin is estimated to underlie these federal lands. Most of this resource potential is accessible under standard lease terms or with restrictions, which are related primarily to controlling surface use for wildlife habitat and riparian ecosystem protection and limiting operations on steep slopes for erosion control. The primary endangered species of concern in the basin is the Indiana bat. Protecting this species can require limited operations for certain periods (generally the bat's breeding season) in some areas.³¹ An interagency study mandated by Congress in the Energy Policy and Conservation Act Reauthorization of 2000 is under way to characterize any impediments to development of oil and natural gas underlying onshore federal lands. Results related to the Appalachian basin are anticipated in 2005.

State lands

State and local governments in the region control significant amounts of land for parks, recreation, reforestation, and other uses. Access to state-owned lands is subject to site-specific requirements. Some lands, such as state parks, have legal or constitutional use restrictions. On other lands, multiple uses, including oil and gas development, may be allowed depending on specific circumstances.

Even on lands available for oil and gas development, some members of the public may perceive such development to be an intrusion that would interfere with other uses, such as recreation, and may feel a sense of personal ownership of these lands. For these reasons, oil and gas development on state and local government lands can be subject to heightened restrictions to protect environmentally and publicly sensitive areas, such as endangered wildlife habitat, steep slopes, riparian ecosystems, and trails and other recreation areas.

Several Appalachian and Illinois basins states border on the Great Lakes. Thirteen wells have been drilled directionally from the Michigan coastline of Lake Michigan and Lake Huron, and more than 2,000 wells have been drilled under Lake Erie from Canada. However, in response to

public opposition, Michigan suspended such drilling, and a Congressional moratorium was established through 2007 on drilling in the Great Lakes. In 2005, Congress legislated a permanent ban.

Coal resource interface

Competing **mineral rights** also can complicate access to resources in the basins. Many areas with potential for natural gas production – including coalbed gas – had historically been leased for coal mining. Many lease agreements date to the late 1800s, under terms that might be interpreted as ambiguous. Today, if an oil and gas operator wants to drill for gas in an area previously leased to a coal operator, a legal dispute frequently arises over who owns the rights to the gas within the coalbeds.³² Legal precedent must be established in each state to decide the issue, and even then, unique circumstances can lead to prolonged legal entanglements. This problem has loomed large over prospective coalbed natural gas operators and has stopped production of this resource in some areas. Several states have passed legislation allowing development of the resource while ownership issues are settled. In states passing such legislation, an increase in production often quickly results.



In the Appalachian and Illinois basins, more than 10 million acres are managed by state governments. Leasing for oil and gas development on state lands is not new to the basins. For example, it has existed since the 1940s in Pennsylvania and since the 1930s in New York. Drilling and operation plans are adjusted to protect the environment and public safety and to reflect surface-management goals for each location.

Suburban growth

Another factor affecting access to oil and natural gas resources is urbanization. While much of the Appalachian and Illinois basins region was rural in the early days of development, energy production now must be balanced with competing urban and suburban land uses. For example, as part of House Bill 278, Ohio enacted a statutory amendment in 2004 for special well permitting to address conflicts that can arise between population centers and oil and natural gas producers. The amendment places regulatory authority in suburban areas with the state oil and gas agency, eliminating duplicative regulatory layers caused by a myriad of local ordinances. The legislature also enacted safety, environmental, and aesthetic requirements to address the unique circumstances caused by high populations in proximity to oil and gas wells.

Valuable resources available to Ohio communities include a first-of-its-kind, comprehensive training manual, *Responding to Oilfield Emergencies*, along with a facility to train local emergency responders on effective practices for oil field sites. These resources were developed by the Ohio Oil and Gas Energy Education Program (OOGEEP). In addition, the Ohio Department of Natural Resources Division of Mineral Resources Management provides a web site designed to improve response times to oil and gas well emergencies, facilitate compliance with spill-reporting requirements, and provide more efficient and accessible community-right-to-know reporting. The web site, developed by Argonne National Laboratory with funding from DOE, serves as a model for other states with oil and gas production operations.



This fenced-in well (foreground) illustrates how unobtrusive production operations can be in suburban locations.

Along with OOGEEP, other educational programs in the region are working to increase public awareness of the oil and natural gas industry and to promote safe, productive, and environmentally sound operating practices. The Illinois legislature established an energy education program in 1999, and the Independent Oil and Gas Association of New York is currently seeking to create such a program. Several states participate in the National Energy Education Development (NEED) project, and, through a U.S. EPA grant, the IOGCC's Energy Education Partnership and the West Virginia Department of Environmental Protection have conducted workshops for school teachers on coalbed natural gas.

Prerequisite 3: Infrastructure expansion

Operators in the Appalachian and Illinois basins are often not far from an interstate gas transmission line to one of the major gas hubs. In fact, a significant portion of the nation's natural gas supplies flows through the Appalachian and Illinois basins. This proximity is a competitive advantage because the operators do not have to deal with price discounts experienced by producers further from the market, such as those in the Rocky Mountain West. For example, an operator in West Virginia can sell gas at the Dominion Hub and incur minor transportation costs, realizing a greater "well-head net back" than an operator in Wyoming selling at the Cheyenne Hub.

However, not all of the resource potential in the basins currently has access to the existing infrastructure, either because the resource exists far from a pipeline or storage access point or, more often, because nearby pipelines and storage fields are already operating at or near full capacity. As new production from these basins comes on line, shortages of transportation capacity can become significant barriers to further development.

Underground storage will play an increasingly prominent role in balancing supply and demand, in both the short term (based on weather) and the longer term (in response to changing structural

supply/demand changes). Gas storage capabilities must expand and become more flexible as natural gas increasingly serves the power generation and home heating markets in the Northeast in addition to its traditional industrial consumers.

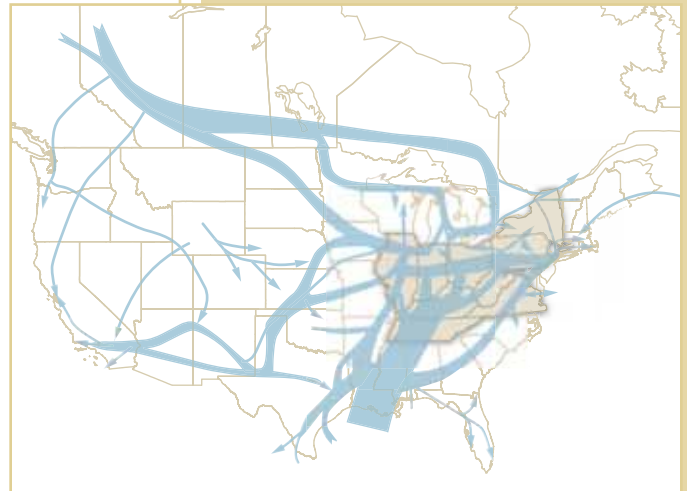
The effective development of resources in the Appalachian and Illinois basins is confronted with a “chicken-and-egg” dilemma. New production needs access to a pipeline to be profitable, and new pipeline capacity needs production to be viable. The fundamental question is who assumes the initial risk. For example, much of the natural gas development under way in eastern and southeastern Kentucky is currently constrained because of inadequate capacity. To address this type of dilemma, the state of Kentucky recently passed legislation establishing the Kentucky Gas Pipeline Authority, which is authorized to provide financing mechanisms – including issuing revenue bonds – to facilitate the implementation of natural gas and coalbed natural gas projects related to storage, gathering, and transportation.³³

Increasing pipeline access to new supplies in the Appalachian and Illinois basins may be constrained by public opposition and the sometimes lengthy and burdensome process by which government and industry attempt to resolve land use and environmental concerns. For example, state concerns were raised as part of consistency review under the Coastal Zone Management Act that prevented the Millennium pipeline project, which was intended to transport natural gas from western New York State to New York City, from being approved. Concerns at the state level also substantially delayed the Islander East pipeline project originating in Connecticut and crossing into New York.

Additional gas gathering compression and processing also may be required to bring new supplies from the Appalachian and Illinois basins.³⁴ The quality of most gas produced in the basins allows it to be input into the existing pipeline system with minimum preparation (generally, simply the removal of water). However, gas produced in the future may be of lower quality, requiring additional processing to meet pipeline specifications. One concern to producers is how “gas gathering” operations may be regulated in the future. Federal pipeline safety law³⁵ requires that the Department of Transportation (DOT) define the term “gathering line” to develop an inventory of those lines and to identify a class of regulated gathering lines that warrant some safety regulation. At issue for producers is establishing a clear point where production ends and gathering begins, a regulatory distinction that in the past has been, at best, ambiguous. Some industry trade groups are urging DOT to adopt American Petroleum Institute Recommended Practice 80 – an industry consensus standard defining both “production facility” and “gathering lines.” Establishing regulatory stability related to pipeline construction and operation is an important goal for the regulated community, particularly for the Appalachian oil and gas industry.

Proximity to markets

A significant portion of the nation's natural gas supplies flows through the Appalachian and Illinois basins. While the existing infrastructure for transportation and storage in the region is extensive, some expansion will be necessary to ensure that new production from the basins can be effectively brought to the market.



The high-deliverability Stagecoach facility is the easternmost underground natural gas storage facility in the United States. This facility was recently sold by Central New York Oil and Gas Company to Inergy L.P. The facility has a maximum withdrawal capacity of 500 MMcf/day to meet the peak gas needs of the eastern United States.

Prerequisite 4: Access to high-quality data

Access to high-quality data about the extent, maturity, and diversity of oil and natural gas resources and about production histories of existing fields is invaluable to potential developers and other stakeholders. Good data enable the identification of new prospects, increase the likelihood of successful exploration and production, and assist state agencies in monitoring the progress of development and ensuring use of appropriate environment safeguards.

Data accessibility

Currently, the accessibility of resource and production data related to the Appalachian and Illinois basins varies from state to state, with limited consistency in scope or quality. With regard to coalbed natural gas, available data are sparse for areas outside known productive regions. Only a handful of older gas-content

analyses are available for all of Ohio and eastern Kentucky, for example. Of the more than 30 potential coalbeds in the region, relatively few have been tested in any one area. Several research efforts are under way in the Illinois basin to obtain additional gas content analyses and other reservoir characterization data. Similar regional characterization work, including water analyses, is needed in the Appalachian basin in order to more fully evaluate the potential for production as well as to establish the proper regulatory framework for managing development.

Improved data on deeper geological formations also will be important in the Appalachian and Illinois basins. Most production in the basins to date has come from relatively shallow depths, and deeper formations have been little explored. Developing a better geological characterization of these deeper horizons is critical to assist in the exploration for additional oil and gas reserves. State geological surveys, in cooperation with industry, play a critical role in developing and disseminating such data.

Highlights of innovation in state agency data management

Illinois	While more than 3.2 billion barrels of oil have been produced, increased production of remaining oil resources will depend on access to large amounts of data and effective data evaluation and management. The Illinois Oil and Gas (IL OIL) project, funded by DOE, was designed to alleviate data access constraints by developing techniques for evaluating underdeveloped areas in and around petroleum reservoirs in Illinois. The Illinois State Geological Survey statewide database was used to develop a series of interactive maps with well locations color-coded by producing horizon. The maps can be presented either as a single-pay horizon or layered to show multiple horizons. A second series of maps that identify underdeveloped areas has been created from a waterflood database. ³⁶
Indiana	The Indiana Geological Survey's Petroleum Database Management System (PDMS) is an online tool used to manage and process information related to petroleum test wells. The database contains information on more than 70,000 petroleum-related wells drilled in Indiana, including well locations, completion zones, logs, operators, lease names, tests, hydrocarbon shows, samples, cores, geologic formations and tops, and much more. The PDMS is used to generate maps that show petroleum wells, oil and gas fields, production, and other data in standardized and custom formats.
Kentucky	The Kentucky Division of Oil and Gas has developed a comprehensive database documenting more than 110,000 wells. The Division uses handheld computers in the field to record facility inspection data. GIS and GPS capabilities enable field inspectors to collect or verify the accuracy of well location data. Public access to oil and gas well data is through the web-based system implemented by the Kentucky Geological Survey. The system includes access by user query, an interactive map interface, scanned images of geophysical logs and well records, and data that can be downloaded for use in mapping software. Kentucky is a national leader in digital geologic mapping, having digitized 707 1:24,000-scale surface geologic maps compiled by a cooperative mapping project with the U.S. Geological Survey between 1960 and 1980.
Ohio	The Ohio Division of Mineral Resources Management led national efforts to develop the Risk-Based Data Management System and forged the way for other states to make the transition from paper to electronic repositories. Innovations include Ohio's Emergency Response Oil and Gas Well Locator web site, which allows emergency response personnel to locate wells and provides contact information and locations of nearby schools, hospitals, roads, and bodies of water. The emergency web site is used by the Ohio oil and gas industry to electronically submit SARA Title 3 community right-to-know information, eliminating the requirement for multiple copies of paper reports and providing first responders immediate electronic access to stored chemical information in an emergency situation.

States are continuously working to improve access to information about oil and natural gas resources, production, and operations in the basins. For example, the Illinois State Geological Survey and the Midwest Petroleum Technology Transfer Council recently introduced a service that allows online searches of historical well data in map form. Other efforts include studies by state geological surveys on emerging plays, such as the Trenton/Black River, New Albany Shale, and coalbed natural gas.

Risk-based data management

For many years, the Ground Water Protection Council, a national association of state ground water and underground injection control agencies, has worked to develop better ways to protect and conserve ground water resources. One of the major products of this effort has been the risk-based data management system (RBDMS), a mature electronic data management system underwritten by DOE funding, which is now being used in 21 states including Kentucky, Ohio,

Pennsylvania, and New York, to manage their oil and gas information and to make better regulatory and resource management decisions. Developed originally as a way to manage the data needed to protect underground sources of drinking water, RBDMS has evolved to include oil and gas production and permitting data, wellbore schematics, geographic information system capability, Internet access, and electronic permitting and reporting. Attributes of RBDMS include its use of nonproprietary software, its capability to address legacy databases, and its adaptation to variations in state oil and gas regulatory and production accounting methods.

RBDMS enables increased environmental protection by allowing rapid access to data needed by regulatory agencies to assess environmental risk of oil and gas operations. It significantly reduces costs for industry compliance and increases government efficiency. Future priorities include continuing the development and implementation of national e-commerce solutions for oil and gas regulatory agencies and industry.

Pennsylvania The Wells Information System (WIS) is a comprehensive database created by the Pennsylvania Geological Survey that stores details associated with drilled oil and gas wells, as well as undrilled, canceled, void, or expired drilling permits. This relational database allows for the entry, storage, access, and analysis of data through linked data fields. Survey staff members augment the database daily, based on data reported by oil and gas companies. A geographic information system linked to WIS can be used to create "oil and gas base maps" showing the locations of wells and other important geographical information.³⁷

West Virginia West Virginia has developed an atlas of major Appalachian gas plays, a 200-page compendium containing maps and descriptions of key gas fields in each of 30 gas plays in the Appalachian region. A companion database includes information on more than 5,100 individual gas reservoirs. Both the atlas and database were developed by the Appalachian Oil and Natural Gas Research Consortium at the West Virginia University. The consortium conducts multidisciplinary research on petroleum and natural gas technology, in partnership with five state geological surveys (West Virginia, Ohio, Pennsylvania, New York, and Kentucky). New analytical approaches have led to more accurate calculations of the nation's known and potential gas resources, including unconventional resources such as low-permeability "tight" gas reservoirs, gas shales, and coalbed natural gas.

New York The New York Division of Mineral Resources has developed a comprehensive RBDMS database that includes regulatory and status information on more than 35,000 wells, annual well reporting, and state land oil and gas leasing revenue and status tracking. Other enhancements include an electronic production reporting system that accounted for more than 94 percent of gas production last year and a PDA field inspection system. DOE funding through the Ground Water Protection Council made the database development possible. The database is linked to geographic information systems and the division's web site and is also shared with the New York State Museum's Empire State Oil and Gas Information System (ESOGIS), which provides enhanced Internet access to well data, including well completion reports and logs.

Smart energy/environmental solutions

Numerous policy and regulatory issues affect oil and natural gas supply and delivery in the basins. Efforts have been under way in state and federal agencies to achieve regulatory efficiency and establish more cost-effective, risk-based regulations based on sound scientific and technical information.

Regulatory jurisdiction over hydraulic fracturing. Hydraulic fracturing is used on thousands of wells every year to improve their productivity. Use of this long-established technique was threatened by litigation that would require unnecessary or duplicative regulation, adding to exploration and production costs. In response to public concerns and this legal challenge, a study by EPA concluded that hydraulic fracturing in coalbeds poses little or no threat to groundwater.³⁸ In 2005, Congress affirmed that hydraulic fracturing is not “underground injection” for the purposes of Safe Drinking Water Act regulation.

Storm water construction permitting. In 2003 EPA issued regulations for smaller municipal storm sewer systems and construction sites that disturb from one to five acres. Most onshore oil and gas well sites disturb from one to five acres and therefore could have been subject to these requirements. Although exploration and production facilities were exempted from the requirements, EPA interpreted this to not apply to construction that precedes exploration and production operations, such as road building and well site construction. Industry and states challenged this interpretation in court, and EPA deferred implementation of the regulations until 2006 pending further review of the exemption and the large potential costs and energy impacts. Existing industry and government standards, in some cases established for other purposes such as site preparation and erosion control for stabilizing drilling equipment, address the management of storm water discharges at oil and gas sites and reduce the potential for adverse impacts on water quality. In 2005, Congress extended the exemption to include oil and gas construction sites.

Spill prevention, control, and countermeasure (SPCC) plans. Exploration and production facilities are currently required to prepare SPCC plans. However, in July 2002 EPA issued regulations that would impose potentially burdensome new requirements on these facilities. EPA has extended compliance dates to reconsider elements of the rules and to attempt to address potential economic implications.³⁹

Orphaned wells. Most states in the region have existing programs to address the problem of orphaned wells (wells with no known operator). Most require operators to post a bond that covers well plugging and site restoration in cases where the operators do not perform their regulatory obligations. Orphaned wells for which no bond has been established may be remediated using state plugging funds, which are generally derived from well permitting surcharges. State/Industry partnerships have successfully rehabilitated wells that would otherwise have been permanently abandoned and have properly plugged numerous unproductive wells in a cost-effective manner.⁴⁰ In 2005, Congress authorized new initiatives for addressing orphaned wells on federal, state and private lands in ways that aim to be practical, economic and protective of the environment.

Prerequisite 5: Environmental stewardship

Ensuring adequate supplies of energy to support economic growth and to meet consumer demand must be accomplished while protecting the environment. Industry, government, and the public all have roles in environmental stewardship.

The Appalachian and Illinois basins span ten states with strong and mature regulatory programs that effectively strike a balance between the orderly development of energy resources and environmental protection and public safety. Policies and procedures have been established that are responsive to the needs of citizens and the environment as well as the needs of permit applicants. With relatively small areas of federal lands in the basins, permit applicants deal primarily with state permitting authorities that have the ability to respond to permit applications thoroughly and rapidly. Since many wells in the basins are stripper wells – with economic viability that can be jeopardized by increased costs – efficient and responsive regulatory programs are the norm in the region.

At the federal level, the states in these basins are subject to regulation by four different Environmental Protection Agency (EPA) regional offices (regions 2, 3, 4, and 5). While there are many similarities in the content and administration of state-mandated programs, differences sometimes arise between federal and state regulatory requirements. Some states in the basins implement federal regulatory programs directly by acquiring federal approval through a process known as primacy, while other states opt to have EPA implement directly.

The continuation of a balanced regulatory approach – one that ensures environmental protection while developing oil and gas supplies – is critical for energy production to remain viable and grow in the Appalachian and Illinois basins.

State agencies continually strive to achieve statutory objectives while emphasizing customer service to public and industry citizens, landowners, and small businesses (such as independent oil and gas operators, who benefit from program efficiencies in the region). The Appalachian and Illinois basins programs meet regularly to compare policies, procedures, and technologies, in order to increase consistency and effectiveness across the region.

Such efforts are facilitated by STRONGER, or the State Review of Oil and Natural Gas Environmental Regulations. STRONGER was formed in 1999 to carry forward the state review process begun cooperatively in 1988 by EPA and the IOGCC. STRONGER is a nonprofit, multi-stakeholder organization whose purpose is to educate and provide services for the continuous improvement of regulatory programs and industry practices in order to enhance human health and the environment. The state review process – in recent years funded by EPA, DOE, and the American Petroleum Institute – is not mandatory and relies on states to volunteer for reviews. Since 2001, reviews have been conducted in Indiana, Ohio, Pennsylvania, Virginia, and West Virginia. New York and Kentucky are scheduled for their second, or follow-up, review in 2006.

Despite the strong and mature programs in the region, ongoing program maintenance is needed to keep up with changing technologies and customer needs. Continued vigilance assures that proper levels of financial and public policy support is provided by governments to maximize safe, effective, and orderly development of energy resources in the region. In particular, as industry recognizes the potential of these basins, exploration and development activity is likely to increase, and the personnel and resources required to facilitate appropriate oversight must change accordingly. In response to this concern, the Petroleum Technology Transfer Council has held several training sessions for well tenders in the Appalachian and Illinois basins in the past two years.



Next Steps

Encouraging resource development and economic growth through basin-wide strategies

Key decision makers affecting oil and natural gas supply and delivery in the Appalachian and Illinois basins

State oil and gas regulatory agencies

State geologic surveys

State departments of natural resources and environmental quality

State lands commissions

State fish and game commissions

State historic preservation offices

State and regional economic development agencies

State public utility commissions

State legislators

Municipalities

State universities

Research and technology transfer organizations

Federal agencies

- Environmental Protection Agency
- Department of Energy
- Department of Agriculture
- U.S. Forest Service
- Department of the Interior
- Bureau of Land Management and Fish and Wildlife Service
- Department of the Treasury
- Department of Transportation
- Federal Energy Regulatory Commission

Private landowners

Consumers

Private citizens

Public interest groups

Financial community

Individual companies and trade associations

Oil and natural gas production from the Appalachian and Illinois basins already makes a far-reaching contribution to the regional economy – generating jobs, tax revenues, and benefits to businesses and consumers. Prospects for boosting these contributions through increased resource recovery are promising. The Appalachian and Illinois basins remain rich in hydrocarbon resource potential that, increasingly, can be produced economically with advanced exploration and production technologies.

Realizing this potential will take action by a range of private and public stakeholders to address five prerequisites:

- **Technology progress.** Advanced technologies must be developed and applied to extend the lives of wells and to economically find and produce resources in challenging settings.
- **Access to resources.** Supportive policies are needed to provide access to resources on public lands in an environmentally sound manner, to resolve mineral rights conflicts, and to address unique access issues in urbanized areas.
- **Infrastructure expansion.** Expansion of natural gas pipelines, gathering systems, and storage will be required to bring new production in the basins to market.
- **Access to high-quality data.** Potential investors in the region will require access to large amounts of data on resources and production, coupled with effective data analysis and management.
- **Environmental stewardship.** Strong and responsive regulatory programs, incorporating cost-effective regulatory strategies, are essential to balance energy production and environmental protection.

Collaborative approaches and basin-wide perspectives will be fundamental in tackling these prerequisites and accelerating recovery of natural gas and oil from the Appalachian and Illinois basins. Diverse stakeholders have an interest in the responsible recovery of these resources (see sidebar), not only to meet domestic energy needs, but also to stimulate economic growth in the region. Several public-private efforts – such as the Appalachian Oil and Gas Research Consortium – are already under way to encourage productive dialogue among these stakeholders. In addition, officials from the Appalachian and Illinois basins states meet regularly to share information and best practices for resource conservation and responsible development.

Other collaborative strategies may be valuable in leveraging technology to its fullest potential in the region. For example:

- Public-private partnerships might be pursued to focus on the development and application of advanced oil and natural gas supply technology.
- State geologic surveys should be granted additional funding to provide more and better information on the characteristics of the potential hydrocarbon resources remaining in these basins.
- Providing financial incentives for unconventional gas and enhanced oil recovery technologies is another possible strategy to stimulate their application in new areas.

Some opportunities would require concerted efforts by multiple industries and government entities. One example would be a regional effort to capture industrial carbon dioxide for use in CO₂-enhanced oil recovery, thereby increasing oil production in the region and reducing atmospheric carbon emissions. Likewise, providing the necessary new gathering, transportation, and

storage infrastructure to move increased natural gas supplies to market may call for joint ventures or similar risk-sharing relationships between producers and pipelines.

Clearly, effective basin-wide strategies must be based on input from the diverse group of stakeholders involved. As an initial step, the IOGCC's Appalachian and Illinois Basin Directors could begin conducting a series of stakeholder workshops designed to develop such basin-wide strategies. Recommendations coming out of this process on actions required to carry out the strategies could then be forwarded to state and federal policy makers, along with the key participants from industry.

Implementing basin-wide strategies to effectively pursue the large remaining hydrocarbon resource base in this region will be challenging. Yet the prospective returns to our nation – and to the Appalachian and Illinois basins states – justify concerted efforts. Our nation's energy security and economic growth can be enhanced by tapping the youthful potential of these mature basins.



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All web site citations as of August 2005

Appendix: Informational Resources

Key links

Interstate Oil and Gas Compact Commission
www.iogcc.oklaosf.state.ok.us

The U.S. Department of Energy's Office of Fossil Energy pursues the DOE mission to foster a secure and reliable energy system that is environmentally friendly and economically sustainable. DOE conducts research on advanced energy technologies and provides scientific, technical, and other information to inform industry and government decision making.
www.fossil.energy.gov

The National Energy Technology Laboratory Strategic Center for Natural Gas & Oil implements DOE's Office of Fossil Energy Natural Gas and Oil research and development programs. www.netl.doe.gov/scngo/

The Independent Petroleum Association of America represents thousands of independent oil and natural gas producers and service companies across the U.S.
www.ipaa.org

State oil and gas agencies foster the responsible development of oil and natural gas resources in a manner that is protective of human health and the environment. For the Appalachian and Illinois basins, they are:

- Illinois Dept. of Natural Resources, Division of Oil and Gas www.dnr.state.il.us/mines/
- Indiana Dept. of Natural Resources, Division of Oil and Gas www.in.gov/dnroil/
- Kentucky Office of Mine Safety and Licensing, Division of Oil and Gas www.dmm.ky.gov/oandg/
- Maryland Dept. of Natural Resources www.dnr.state.md.us/
- New York State Dept. of Environmental Conservation, Division of Mineral Resources www.dec.state.ny.us/website/dmn/
- Ohio Dept. of Natural Resources, Mineral Resources Management www.dnr.state.oh.us/mineral/index.html
- Pennsylvania Dept. of Environmental Protection, Bureau of Oil and Gas Management www.dep.state.pa.us/dep/deputate/minres/oilgas/oilgas.htm
- Tennessee Division of Geology, Oil, and Gas Section www.state.tn.us/environment/permits/oil&gas
- Virginia Dept. of Mines, Minerals, and Energy, Division of Gas and Oil www.dmme.virginia.gov/dgo
- West Virginia Dept. of Environmental Protection, Office of Oil and Gas www.wvdep.org

State geological surveys provide science-based information on each state's geology and mineral and water resources to citizens, researchers, industry, and government. Some state geological surveys have regulatory responsibilities for water, oil and gas, land reclamation, and other issues. Surveys for states in the Appalachian and Illinois basins can be found online:

- Illinois www.isgs.uiuc.edu
- Indiana <http://igs.indiana.edu>
- Kentucky www.uky.edu/KGS
- Maryland www.mgs.md.gov
- New York State www.nysm.nysed.gov/esogis
- Ohio www.ohiodnr.com/geosurvey
- Pennsylvania www.dcnr.state.pa.us/topogeo
- Tennessee www.state.tn.us/environment
- Virginia www.dmme.virginia.gov/dmr
- West Virginia www.wvgs.wvnet.edu

Related links

The Petroleum Technology Transfer Council assists U.S. independent oil and gas producers in making timely, informed technology decisions by identifying and clarifying producers' needs, educating producers about technology options, and connecting producers to solutions. www.pttc.org

The industry-driven Stripper Well Consortium develops, demonstrates, and deploys new technologies needed to improve the production of oil and natural gas stripper wells. www.energy.psu.edu/swc/

The Gas Storage Technology Consortium assists in the development, demonstration, and commercialization of technologies to improve the underground storage of natural gas/hydrocarbons. www.energy.psu.edu/gstc/

The Ohio Oil and Gas Energy Education Program encourages oil and gas curricula in the classroom and promotes public awareness about the industry. www.oogeep.org. A similar organization in Illinois can be accessed at www.iprb.org.

The National Energy Education Development (NEED) project promotes an energy-conscious and educated society by engaging students and educators, along with business, government, and community leaders, to design and deliver objective, multisided energy educational programs. www.need.org



Oil and natural gas produced in the Appalachian and Illinois basins help to meet the rising energy demands of industries and other consumers. Technology progress is one key to tapping important new energy resources in this region.



*Interstate Oil and Gas Compact Commission
Oklahoma City, Oklahoma
www.iogcc.state.ok.us*



*U.S. Department of Energy
Office of Fossil Energy
Washington, D.C. 20585
www.fossil.energy.gov*



*National Energy Technology Laboratory
Strategic Center for Natural Gas and Oil
www.netl.doe.gov*

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