The Economics of Deep Drilling in Oklahoma

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Introduction

This report examines the economic implications for Oklahoma of the natural gas industry's ongoing shift to deep resources in order to meet the growing domestic demand for natural gas. Technological advances and the recent upward shift in baseline energy prices have combined to enhance the economic viability of drilling for deep reserves below 15,000 feet. Oklahoma is home to some of the nation's most plentiful deep gas reserves, and the state's energy companies have played an active role in drilling "deep wells" for more than three decades.

Using a database of production and cost data on wells drilled at all depths in Oklahoma since 2000, the findings indicate that the expected economic impact increases along with well depth and is of a much larger magnitude for deep wells versus traditional shallow wells. The expected impact is greater for deep wells because drilling becomes increasingly costly and the expected level of gas production is much greater as the depth of the well increases.

The Increased Role of Deep Drilling

World and domestic demand for energy are growing faster than projected, especially for natural gas. Throughout the 1990s, annual consumption of natural gas grew from 19.3 TCF (trillion cubic feet) to nearly 22 TCF. The National Petroleum Council's September 2003 report projects that demand for natural gas is likely to increase to 26 TCF in 2020 and could increase beyond 31 TCF by 2025.[2] Two major forces are driving this increased demand - wider use of natural gas for electricity generation and growing concerns about the adverse environmental effects of burning coal and fuel oil.

U.S. gas consumers are primarily dependent on U.S. production for the increased demand because natural gas cannot be easily transported by pipeline from distant areas of the world with substantial reserves. In addition, U.S. production is in a long-term decline and most of the easily accessible gas-producing areas offer limited production potential. Much of what remains is found in the reservoirs of expensive-to-reach deep gas fields.

The development of domestic deep gas resources is one way to ensure that the nation's growing demand for natural gas can be met. In a comprehensive 1995 assessment of U.S. oil and gas resources, the U.S. Geological Survey (USGS) estimated that onshore undiscovered and recoverable "deep" natural gas resources below a depth of 15,000 feet totaled 114 trillion cubic feet.[3] Drilling and exploration companies in the U.S. are intensifying their efforts to recover these deep natural gas deposits. The U.S. Department of Energy (DOE) estimates that approximately 300 deep wells were drilled onshore in 2004 and forecasts a steady increase in deep drilling to 350 wells in 2007.[4]

Offsetting the high cost of deep drilling is the potential payoff in significantly higher average production rates of deep versus shallow wells. Estimates indicate that deep wells below 15,000 feet comprise only 0.5 percent of producing gas wells, but account for 6 percent of the natural gas produced through 2002.[5] The overall success rate of deep wells has been remarkably good. In a sample of 20,715 deep wells drilled in the U.S. through December 1998, 11,522 (56 percent) are classified as producing gas and/or oil wells, with gas wells comprising nearly 75 percent of producing wells. Of the 1,676 wells exceeding 20,000 feet, 974 (58 percent) are producing wells of which 847 are gas wells.[6]

In recognizing the increasingly important role of deep wells, especially in natural gas production, the DOE's National Energy Technology Laboratory recently funded a research and development program known as "Deep Trek." The program calls for the development by 2010 of "smart" drilling techniques capable of withstanding the extreme conditions of deep drilling. In making the commitment to deep drilling technology, DOE cites the National Petroleum Council's projection that by 2010, 41 percent of natural gas production will come from depths below 10,000 feet and 12 percent of all gas production will come from wells below 15,000 feet.[7]

Advances in computer technology have already produced breakthroughs in reservoir modeling that enable better estimates of the size and location of recoverable deposits. Likewise, technological improvements in drilling and recovery have expanded the ability to increase the resource base. An early release from an ongoing U.S. Department of Energy study indicates that technological advancements reduced the average time to reach a depth of 17,000 feet for two East Texas deep wells drilled in the same structure from 170 days to 70 days between 1985 and 2002.[8]

Deep Drilling in Oklahoma

Oklahoma has long played an important role in the development of deep drilling. The first hole drilled below 30,000 feet for commercial production purposes was completed in Beckham County in 1972. In 1974, drilling commenced on GHK/Lone Star's Bertha Rogers 1-27 in Washita County, eventually reaching a world record depth of 31,441 feet. Both of these wells are located in the Anadarko Basin, an east-west trending basin in west central Oklahoma (see Figure 1). Smaller potential deep reserves exist in the Arkoma Basin, an east-west trending basin in eastern Oklahoma situated near the Ouachita Mountains and stretching into central Arkansas.

The Anadarko Basin has historically been one of the most prolific natural gas producing regions in the United States and is the location of most of the deep wells in Oklahoma. According to the U.S. Geological Survey, 20 percent of the holes drilled deeper than 15,000 feet prior to 1991 are located in the Anadarko Basin, exceeding the number of deep wells in all drilling regions in the U.S. other than the Gulf of Mexico in the period.[9] Through 1998, 19 of the 52 existing ultra deep wells below 25,000 feet were drilled in the Anadarko Basin.[10]

Through 2002, the Potential Gas Committee reports that a total of 1,221 producing deep wells were completed in Oklahoma at an average depth of 17,584 feet, with 755 of these wells currently active. The average drilling cost in the 1995 to1999 period was $2.65 million per well

with average recoverable reserves per deep well of 6.36 BCF (billion cubic feet). Cumulative production through 2002 from the state's deep wells totaled 6.464 TCF with estimated potential recoverable gas of 16.2 TCF.[11] These production rates are consistent with a U.S. Geological Survey study that finds an average initial production rate for deep wells in the Anadarko Basin of more than 5,000 MCF (thousand cubic feet) per day. Most wells experienced an initial production rate between 1,000 and 10,000 MCF/day, with the most productive wells exceeding 1,000,000 MCF/day.[12]

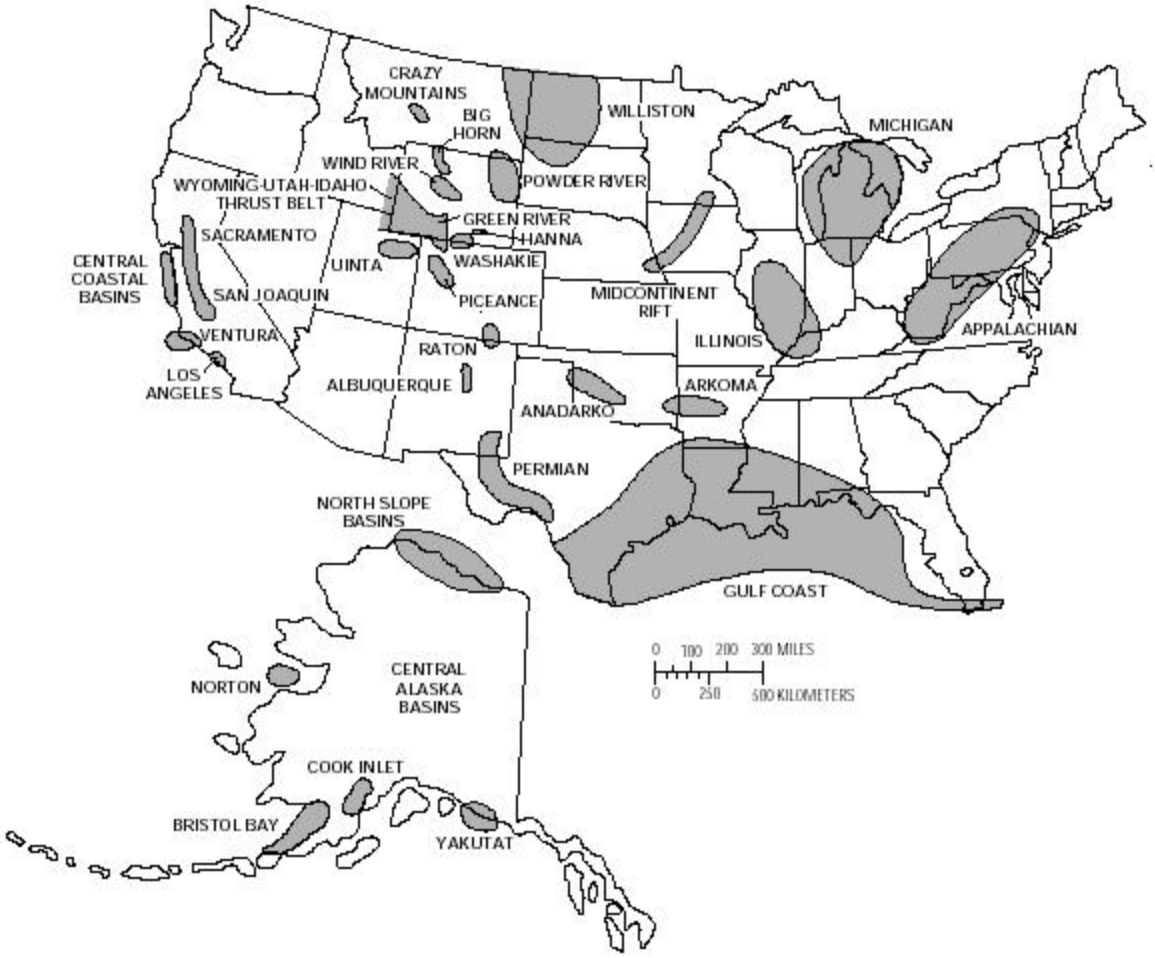


Figure 1. Map of the United States showing basins containing sedimentary rocks more than 15,000 ft. (4,572 m) deep. Shading indicates entire basin area, in which some of the sedimentary rocks are at shallow depths.[13]

Energy and the Oklahoma Economy

Since 1950, Oklahoma producers have extracted oil and gas valued at more than $200 billion from the state's producing fields - approximately $117 billion in natural gas and $87 billion in oil. The oil and gas industry is Oklahoma's largest single industry in terms of output, generating more than $11.5 billion in output from production and an additional $3.5 billion from drilling

and exploration annually. Combined, oil and gas drilling and production account for 8 percent of all goods and services produced statewide.

More than 2,000 firms comprise Oklahoma's oil and gas industry, providing employment for more than 58,000 wage and salary and self-employed workers (2.5 percent of the total state workforce) and generating more than $2.5 billion in income annually. Purchases by oil and gas companies from other state businesses play a vital role in the state economy and total more than $2.5 billion annually. Oil and gas production occurs in nearly all of the state's 77 counties, making the industry an important vehicle for economic development in the rural areas of the state.[14]

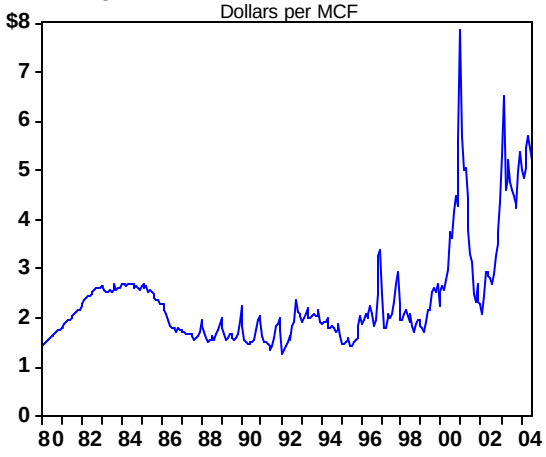
The oil and gas industry also contributes a significant amount of severance tax revenue to support state government programs. Oil and gas producers have paid more than $400 million annually in Oklahoma gross production taxes on average the past 15 years, accounting for between 5 and 10 percent of total state tax revenue in recent years.[15] Much of the revenue is shared with local governments throughout the state and used to fund local school districts, county roads, and other general fund expenditures that have a statewide impact.

There is little doubt that the state's energy industry continues to influence overall state economic activity. A recent research report[16] finds that despite higher energy prices, the economic spillover effects from the state's oil and gas industry continue to provide a net positive stimulus to the overall Oklahoma economy, though the impact is smaller than the pervasive effects experienced during the oil boom and bust periods. Of concern to policymakers is that this strong link between the oil and gas industry and the state economy can work in the adverse direction by producing larger than average negative economic effects on the state economy if oil and gas output continues to decline.

Recent Industry Trends

Oklahoma's energy sector has experienced a rebound along with the nation in response to the rise in energy prices beginning in 2000. Energy price forecasts by Global Insight[17] and the U.S. Department of Energy[18] suggest that we are entering an extended period of high crude oil and natural gas prices (see Figure 2). Both forecast groups argue that the recent upward move in prices will have a long-term residual effect on the baseline price of crude oil and natural gas. Their forecasts for natural gas suggest a baseline price of $5.00/MCF through 2015, a level more than double the average 1990s price. Forecasts for crude call for some price moderation in 2005, but for West Texas Intermediate to continue to trade in the $35-38 per barrel range through next year.

Figure 2. OK Wellhead Natural Gas Price

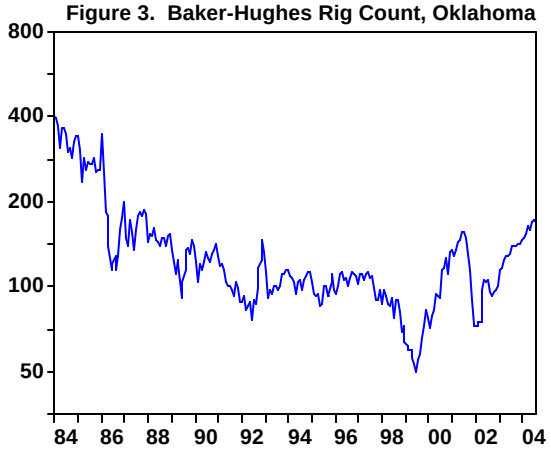


The effect of higher energy prices is reflected in recent state economic activity. In

the past 2 years, 4,400 new oil and gas industry workers have been hired statewide, with 2,800 working in drilling and exploration. New job formation in the energy sector led all other industry sectors in the recent national recession, and provided the state with much-needed countercyclical economic stimulus during the slowdown.[19]

The utilization rate of the existing state oil and gas workforce has intensified as the average workweek expanded from 43.2 hours in 2003 to 46.0 hours 2004. The number of active drilling rigs in Oklahoma (see Figure 3) reflects the recent shift in market fundamentals and is at the highest rate since the statewide collapse in drilling in the mid 1980s.

Figure 3. Baker-Hughes Rig Count, Oklahoma



The added exploration activity across the state is placing tremendous pressure on the market for oil and gas workers and for the inputs to the drilling and exploration process. Rising wages and a shortage of qualified oil and gas workers have worked to push drilling and exploration costs upward. Nationally, average hourly wage rates for oil and gas exploration workers have increased by 11.5 percent in the 24 months ended December 2004.[20] In addition, the recent worldwide surge in steel prices has resulted in a doubling of drill pipe costs since January 2004.[21]

Production in Oklahoma has responded to the recent upward move in oil and gas prices, but significant additional exploration is needed to maintain current production levels. The rate of decline in crude oil production has slowed since 2001 in response to rising prices, but current production remains at approximately 40 percent of the most recent annual peak output level reached in 1984. Natural gas output has expanded slightly since 2002 and has gradually become the state's dominant energy commodity. For 2004, natural gas production will total four times the state's oil production measured either by market value or on a barrel-of-oil-equivalent (using a ratio of 6:1) basis.

Assessing the Economic Impact of Deep vs. Shallow Drilling in Oklahoma

The State of Oklahoma has recognized the role of gas production from deep wells in maintaining energy production in the state and is currently encouraging the development of deep well resources through a temporary severance tax abatement program.[22] Providing incentives for deep drilling reflects the economic potential of deep wells in Oklahoma and makes efficient use of the existing public and private investment in infrastructure in the oil and gas producing areas of the state, including gas transportation.

As production becomes increasingly dependent upon deep resources, it is important to understand how the changing business dynamics of exploration may impact the overall state economy. One of the difficulties in assessing the economic impact of exploration activities is a lack of timely and accurate data on the cost of drilling oil and gas wells. In order to assess the

economics of shifting to deeper drilling, this report uses a dataset comprising cost and production data on wells drilled in Oklahoma since 2000 by Chesapeake Energy. Chesapeake is Oklahoma's largest natural gas producer, its most active operator, and its most active explorer for Oklahoma deep natural gas reserves. The Chesapeake dataset provides a large representative sample of drilling costs and production rates for oil and gas wells at all depths across the state.

Figure 4 summarizes the drilling cost and 2004 production levels for the 1,195 wells in the dataset categorized by depth. The cost estimates include those wells that have incurred all upfront capital costs associated with completing the drilling of the well, regardless of whether the well is yet producing oil or gas. The production estimates include all wells that produced oil or gas in 2004 and include some part year production levels.

Figure 4. Sample of Drilling Activity in Oklahoma Since 2000

	Well Depth (Thou. Feet)			
	0- 5	**5-10**	**10-15**	**15+**
Completed Wells	117	658	302	118
Average Vertical Depth (Feet)	3,044	7,258	12,582	17,518
Average Well Cost*	$287,379	$602,983	$1,793,687	$5,336,126
Average Well Cost per Foot	$94.41	$83.08	$142.56	$304.61
Average Gas Production (MCF, 2004)	20,455	65,614	105,120	790,644
Average Oil Production (Bbl, 2004)	1,761	669	2,134	3,627

* Well cost includes intangible drilling costs and well equipment

The results illustrate how the business model for exploration becomes increasingly capital intensive as well depth increases. Wells in the sample up to 5,000 feet in depth cost an average of $287,000, while deep wells in excess of 15,000 feet cost nearly 20 times more, or an average of $5.3 million to complete. This is approximately double the average cost per deep well cited by the Potential Gas Committee in the 1995 to 1999 period. The average per-foot drilling cost for deep wells ($305/foot) is more than triple the cost of wells under 10,000 feet, and more than double the cost for wells 10,000 to 15,000 feet deep.

Figure 5. Well Depth by Cost

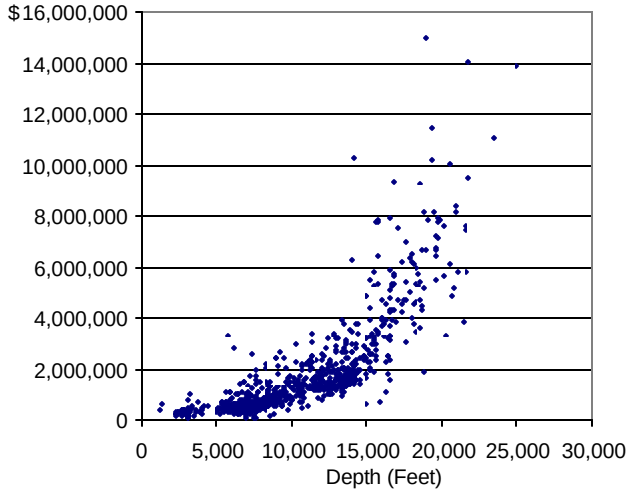


Figure 5 contains the full distribution of well costs by well depth in the sample and illustrates the more than proportionate increase in cost relative to the depth of the well. Most wells under 10,000 feet cost less than $1.5 million to complete, while many deep wells cost significantly more than the $5.3 million average for deep wells, reaching nearly $15 million for the most costly well in the sample.

The production rates in Figure 4 also illustrate the potential payoff from deep drilling. The average gas production in 2004 for wells less than 5,000 feet deep was 20,455 MCF, versus 790,644 MCF for deep wells in excess of 15,000 feet. Deep wells produce 11 times more output than the average of all wells less than 15,000 feet deep, and 40 times more output than all wells less than 5,000 feet deep. For comparison, in 2004, the 93.3 BCF of gas produced from the 118 deep wells in the sample exceeded the 73.3 BCF produced by the 1,077 wells under 15,000 feet in the sample. In fact, the production of the 118 deep wells alone will comprise nearly 6 percent of total natural gas production statewide in 2004.[23]

While the expected economic impact per dollar spent on drilling and production is essentially the same for both shallow and deep wells, the much larger upfront investment in drilling costs and proportionately greater production of gas from deep wells generates a larger total economic impact on the state economy. Economic impact estimates indicate that each additional $1 million spent on deep oil and gas drilling in the state provides employment for 6 oil and gas workers with annual earnings of $282,000. Through multiplier effects, these direct impacts from drilling support an estimated 8.5 additional jobs statewide with earnings of $265,000. A typical deep well at a cost of $5.3 million will support 32 oil and gas workers with annual earnings of $1.49 million. Multiplier effects support an additional 45 jobs statewide with annual earnings of $1.41 million. In short, a deep well is estimated to produce approximately 6 times the economic impact of a typical well drilled less than 15,000 feet deep.

Oil and gas production is much less labor intensive than drilling but has stronger economic linkages to other Oklahoma industries and produces relatively larger economic multiplier effects. Each additional $1 million spent on production from deep wells supports 3 oil and gas industry workers with annual earnings of $182,000. More than half of the earnings on the production side accrue to self-employed workers. Multiplier effects from the added oil and gas production support an estimated 6.5 additional jobs statewide with earnings of $222,000 annually.[24] Because production from deep wells is 11 times that of wells less than 15,000 feet deep, the economic impact of production from a deep well is estimated at 11 times that of a typical well drilled less than 15,000 feet deep.

In addition to the larger employment and income impacts from deep wells, royalty payments are significantly higher due to the greater production rates experienced with deep wells. The 118 deep wells in the sample produced $65.7 million in royalty payments in 2004, or more than $550,000 per well. In comparison, the wells in the sample below 15,000 feet produced an average of only $72,000 per well in 2004 royalty income.[25]

Geographic Impact

Deep oil and gas wells in the Chesapeake sample are located in 10 Oklahoma counties, as shown in Figure 6. The bulk of the deep wells are in a large contiguous block of counties in the west central portion of the state surrounding the Anadarko Basin. Approximately one-half of the 118 wells were drilled in Beckham (35) and Caddo (23) Counties. An additional 40 percent of the deep wells are located in three other counties – Roger Mills (17), Stephens (17), and Grady (15). These oil and gas activities continue to exert an important influence on the economic health of these rural areas in Oklahoma.

Figure 6. Sample of Deep Wells Drilled in OK Since 2000 by County

County	Completed Wells	Average Well Depth	Average Well Cost	2004 Average Gas Production (MCF)	2004 Average Oil Production (Barrels)
Beckham	35	19,437	$7,121,116	1,886,836	359
Caddo	23	17,309	5,685,526	520,955	1,010
Canadian	1	15,500	3,110,608	34,343	0
Custer	1	15,250	1,943,532	46,787	1,860
Grady	15	16,388	4,662,809	416,214	4,717
Kiowa	1	15,250	1,976,730	0	0
Latimer	1	16,835	5,331,680	99,549	0
Roger Mills	17	16,448	3,273,526	126,186	110
Stephens	17	16,907	4,858,942	354,735	18,485
Washita	7	16,145	4,157,163	96,456	490
Total	118	17,518	$5,336,126	790,644	3,627

Summary

Deep gas reserves will play an increasingly important role in maintaining production levels in Oklahoma in the coming decades. The historical success of deep drilling in the state coupled with ongoing technological advancements will continue to improve the economic viability of recovering deep gas reserves. Energy price forecasts suggest that the boost provided to the industry from the recent price surge will have a residual effect on the baseline price of oil and gas and enhance the economic long-term potential of deep drilling.

Drilling a deep well is a much more significant economic event than drilling a typical shallow well of past decades. Deep drilling requires increasingly larger capital investments and provides the potential for a comparatively larger economic impact than the typical shallow well. Greater upfront drilling and exploration costs and larger quantities of oil and gas produced translate into added employment and income gains from deep wells. The impact of drilling a deep well provides an estimated economic impact 6 times that of a typical well drilled less than 15,000 feet deep. The production impact of deep wells is estimated at 11 times that of the average well less than 15,000 feet deep.

Endnotes

[1] The article is available online at http://economy.okstate.edu.
[2] "Balancing Natural Gas Policy: Fueling the Demands of a Growing Economy." September 2003. National Petroleum Council.
[3] "1995 National Assessment of United States Oil and Gas Resources." U.S. Geological Survey Circular 1118. 1995. U.S. Geological Survey, National Oil and Gas Resource Assessment Team.
[4] "Benchmarking Deep Drilling and Completion Techniques." John D. Rogers, Stephen W. Lambert, and Steve Wolhart. GasTips. Spring 2004. U.S. Department of Energy.
[5] *Potential Supply of Natural Gas: 2002*. January 2003. Potential Gas Committee.
[6] "Summary of Deep Oil and Gas Wells in the United States Through 1998." U.S. Geological Survey Digital Data Series 67, Chapter B. Thaddeus S. Dyman and Troy A. Cook. 2001. U.S. Department of the Interior, U.S. Geological Survey.

[7] "Natural Gas: Meeting the Challenges of the Nation's Growing Natural Gas Demand." 1999. National Petroleum Council.
[8] "Benchmarking Deep Drilling and Completion Techniques." John D. Rogers, Stephen W. Lambert, and Steve Wolhart. *GasTips*. Spring 2004. U.S. Department of Energy.
[9] "Maps Illustrating the Distribution of Deep Wells in the United States by Geologic Age." Craig J. Wandrey and David K. Vaughn. U.S. Geological Survey Bulletin 2146-B. 1997.
[10] "Summary of Deep Oil and Gas Wells in the United States Through 1998." U.S. Geological Survey Digital Data Series 67, Chapter B. Thaddeus S. Dyman and Troy A. Cook. 2001. U.S. Department of the Interior, U.S. Geological Survey.
[11] "Deep Trek: Deep Gas Wells." 2005. National Energy Technology Laboratory, U.S. Department of Energy. Quoted from *Potential Supply of Natural Gas: 2002*. January 2003. Potential Gas Committee.
[12] "Initial Potential Test Data From Deep Wells in the United States." C.W. Spencer and Craig J. Wandrey. 1997. U.S. Geological Survey Bulletin 2146-F.
[13] "Geologic Controls of Deep Natural Gas Resources in the United States." T.S. Dyman, D.D. Rice, and P.A. Westcott. 1997. U.S. Geological Survey Bulletin 2146–A. U.S. Geological Survey.
[14] "The Local Impact of Oil and Gas Production and Drilling in Oklahoma." Mark C. Snead. October 2002. Oklahoma Commission on Marginally Producing Oil and Gas Wells.
[15] "The Economic Impact of Oil and Gas Production and Drilling on the Oklahoma Economy." Mark C. Snead. October 2002. Oklahoma Commission on Marginally Producing Oil and Gas Wells.
[16] "Energy Prices and the Oklahoma Economy." Mark C. Snead and R. Dale Martinez. September 2004. Center for Applied Economic Research, Oklahoma State University.
[17] Energy Market Analysis. September 2004. Global Insight.
[18] Short-Term Energy Outlook. December 2004, Energy Information Administration, U.S. Department of Energy.
[19] 2005 Oklahoma Economic Outlook, Center for Applied Economic Research, Oklahoma State University.
[20] Bureau of Labor Statistics, Current Employment Statistics, January 2005.
[21] Source: Chesapeake Energy internal tubular contract cost data.
[22] Under current Oklahoma tax law, wells spudded between July 1, 2002 and June 30, 2006 are eligible for an exemption from the gross production tax. The exemption varies as to duration in relation to the depth of the well, where wells 12,500 to 14,999 are exempt for 28 months, wells 15,000 to 17,499 are exempt for 48 months, and wells 17,500 feet or greater are exempt for 60 months.
[23] The estimate of 1662.6 BCF of statewide natural gas production for 2004 is from the 2005 Oklahoma Economic Outlook, Center for Applied Economic Research, Oklahoma State University.
[24] The reported economic impacts are generated from an IMPLAN input-output model of the State of Oklahoma using the 2001 Oklahoma IMPLAN dataset. Estimated oil and gas-related type II employment multipliers are: Oil and Gas Production, 3.10; Drilling Oil and Gas Wells and Support Activities for Oil and Gas Operation, 2.43. For details, refer to IMPLAN Professional: User's guide, analysis guide, data guide. Minnesota IMPLAN Group, 1998. Stillwater, MN.
[25] Source: Chesapeake Energy internal royalty payment data.