A Decade of Progress in Unconventional Gas

Vello A. Kuuskraa, Advanced Resources International, Arlington, VA

Unconventional gas resources - - tight gas sands, coalbed methane and gas shales - - have become a mainstay of the U.S. natural gas industry, Figure 1. From an emerging resource a decade ago, and a mostly overlooked resource two decades ago, unconventional gas is now a core business of many large independent producers and a growing number of the majors. The catch phrase - - "the future is unconventional" - - appropriately captures the trend for this important domestic hydrocarbon resource.

Highlights and Accomplishments. During the past decade, 1996 to 2006, unconventional gas achieved a number of notable accomplishments:

- ***Annual Production***. Unconventional gas production reached a new peak of 24 Bcfd (8.6 Tcf/yr.) in 2006, up from 14 Bcfd (5.0 Tcf/yr.) a decade ago. With a 43% share, it is now the dominant source of domestic natural gas production, Figure 2. All three of the unconventional gas sources increased in annual production during the past decade, Figure 3. Tight gas provided the largest absolute level of production growth during this time, nearly 6 Bcfd (2.1 Tcf/yr.). Gas shales had the largest percentage growth, up by more than 3 fold in the past ten years. Coalbed methane production also increased, from 3 Bcfd in 1996 to nearly 5 Bcfd a decade later.

- ***Proved Reserves and Reserve Additions***. Driven by record well drilling, proved reserves of unconventional gas have also increased to a new record of 105 Tcf at the beginning of year 2006, up from 48 Tcf a decade ago. Today, unconventional gas accounts for more than half of the officially reported 196 Tcf of lower-48 proved reserves of natural gas (EIA, 2006). Significant volumes of probable and possible reserves, as well as a large "undiscovered" resource base, underlie these proved reserves. After

accounting for replacement of production, total unconventional gas reserve additions were an impressive 120 Tcf in the past 10 years.

- ***New and Emerging Plays***. The growth in unconventional gas has been driven by more intense development of emerging gas plays as well as the discovery of several new plays. For example, with aggressive use of infill and extension drilling, the Mesaverde Formation of the Piceance Basin has become a major 1 Bcfd tight gas sand play, up from a modest 0.1 Bcfd prospect a decade ago. With the expansion of Cotton Valley development, the addition of the deep Bossier, and the revitalization of the Travis Peak play, the tight gas sands of East Texas now provide 3.6 Bcfd, up from 1.5 Bcfd ten years ago. Finally, no review of unconventional gas can overlook the amazing development of the Barnett Shale in the Fort Worth Basin, providing nearly 2 Bcfd of production today, up from less than 0.1 Bcf in 1996.

  Gas shales have also been a source of several new unconventional gas plays, particularly the Fayetteville and the Woodford gas shales of the Arkoma Basin. Other new and emerging unconventional gas plays include the low rank coalbed methane play in the Powder River Basin and the deep Wasatch/Mesaverde tight gas sands in the Uinta Basin

- ***Well Drilling.*** Motivated by past advances in technology and expectations of continuing high natural gas prices, a host of producers have entered the unconventional gas arena, driving well drilling and completion to steadily higher levels. From a base of about 5,000 new wells per year (from 1996 to 2000), over 20,000 new unconventional gas wells have been added in each of the past two years, Figure 4. Tight gas sand drilling, at 13,000 wells per year, still dominates with coalbed methane and gas shales each providing 4,000 wells per year. Overall, 102,000 new productive unconventional gas wells have been drilled during the past decade, accounting for about two-thirds of all successful natural gas wells drilled.

- **Overview of Accomplishments and Progress**. With production up by 10 Bcfd, with 102,000 successful wells drilled and completed, and with 120 Tcf of reserves added, clearly this has been a decade of progress for unconventional gas. In the remainder of this and the other articles in this six-part series, we will further examine this past decade of accomplishments and, hopefully, also provide insights on how unconventional gas may fare in the upcoming decade.

Dark Clouds on the Horizon. Even with this list of accomplishments, dark clouds have begun to appear on the horizon for unconventional gas. For many years, progress in technology was able to counter resource depletion, holding the key performance measure, reserves added per well, relatively constant. This, unfortunately, is no longer the case. With reductions in unconventional gas R&D and technology investment (including the termination of the Gas Research Institute and the decline in the DOE gas research and technology program), overall technology progress has slowed considerably. As a result, since the 1996 to 2000 time period, reserves per well for all three of the unconventional gas resources have declined - - and declined sharply, Table 1.

For tight gas sands, well productivity has declined by more than half, from 2.2 Bcf of proved reserves per new successful wells drilled in the 1996-2000 time period, to 1 Bcf per well in the latest, 2003-2005, time period. With the rapid growth in the lower productivity (but also lower cost) Powder River and Mid-Continent coalbed methane plays, reserves per well for this resource have declined even more, from 1.6 Bcf per well in 1996-2000 to 0.5 Bcf per well in the past three years. One partial silver lining is the recent reversal in the decline in well productivity for gas shales. The increasing use of new technology - - multiply-stimulated horizontal wells, particularly in the Barnett Shale - - is one reason for this improvement.

We recognize that higher natural gas prices and the persistent pursuit of efficiency by operators have enabled lower productivity unconventional gas plays, with lower reserves per well, such as the Clinton/Medina tight gas sands in the Appalachian Basin, the Canyon tight gas sands in West Texas, and Wyodak coalbed methane in the Powder River Basin, to be more aggressively developed, contributing to the overall decline in reserves per well. However, the decline in well productivity appears to be a more fundamental problem. For example, of the 43 tight gas plays that Advanced Resources International tracks in our Model of Unconventional Gas Supply (MUGS) data base and model, 20 of these plays had severe declines in reserves per well during just the past three years.

The Good, The Bad and The Ugly. On the "good" side of the ledger, unconventional gas has achieved a number of impressive accomplishments in the past decade. First, there are the new, large (Bcfd) size plays such as the Barnett Shale, the Pinedale/Jonah tight gas sands, and Powder River coalbed methane. Ten years ago many in the industry questioned whether any Bcfd size natural gas plays were even left in the lower-48. Second, the unconventional gas development experience provides solid evidence that increased drilling can and will lead to increased gas production and reserves, counter to the "sound bite" message by some energy analysts that higher levels of drilling are having no effect. For example, with increased well drilling, unconventional gas has been able to more than replace the steep, 5.4 Bcfd (2.0 Tcf/yr.) decline in Gulf of Mexico (GOM) gas production since year 2000, Table 2.

On the "bad" side of the unconventional gas ledger is the decline in technology progress. All of the key measures of the rate of technology progress that we track in MUGS are down. These technology progress measures (levers) include among others: (1) the efficiency and volume of reserves added from well recompletions, resimulations and identification of bypassed pay; (2) the ability to reliably identify and delineate the higher productivity ("sweet spots") portions of an unconventional gas play; (3) the rate of improvements in well drilling and completion efficiency; and, (4) the track record of

success in overcoming environmental and other constraints impeding access to undeveloped resources.

Finally, we turn to the "ugly", the sharp rise in costs and economic risk. Because of the decline in reserves per well and the upward spiral in well drilling and completion costs, much of the unconventional gas resource has become a high cost resource play. Even though oil prices (a reasonable proxy for natural gas prices, except in the past year) have increased by 23% per year since 2002, finding costs for U.S. E&P companies have increased even faster, by 38% per year during this time (Southwestern Energy Company, 2007), Figure 5.

Should natural gas prices decline and remain at $4 to $5 per Mcf (Henry Hub spot price), as seen in the early years of this decade, many of the unconventional gas plays would become uneconomic. Of course, with a drop in gas prices, well drilling and completion costs may also drop, and the associated loss in gas production might then provide a price rebound, unless low cost LNG imports fill the gap.

The Six Part Series. To provide a more in-depth look at this "Decade of Progress in Unconventional Gas," we have prepared a six-part series on topics important to this domestic natural gas resource. This first article will be followed by:

- *Unconventional gas resource base*. How much tight gas, coalbed methane and gas shale resource still remains undiscovered and undeveloped?

- *Emerging unconventional gas basins and plays*. Which of the new and emerging plays and basins hold promise for large future growth?

- *Importance of technology progress for unconventional gas*. How efficient are available E&P technologies in unlocking the increasingly challenging remaining unconventional gas resource base?

- *Economics for unconventional gas*. How much have the combined effects of higher well costs and lower reserves per well impacted the economic viability of unconventional gas?

- *Outlook for unconventional gas*. What does the future hold for tight gas, coalbed methane and gas shale development?

Closing Comments. An important theme in this series of articles is - - we are not running out of domestic unconventional gas resources. Rather, the nature of the remaining undeveloped unconventional gas resource base is shifting rapidly towards more challenging reservoir settings. Continuing, and even accelerating, progress in technology will be essential to efficiently and economically develop this remaining resource base. With the recent formation of the gas technology institute called RPSEA (Research Partnership for Securing Energy for America), there is optimism that investments in unconventional gas R&D will be rebound and "technology progress will, once again, keep ahead of resource depletion."

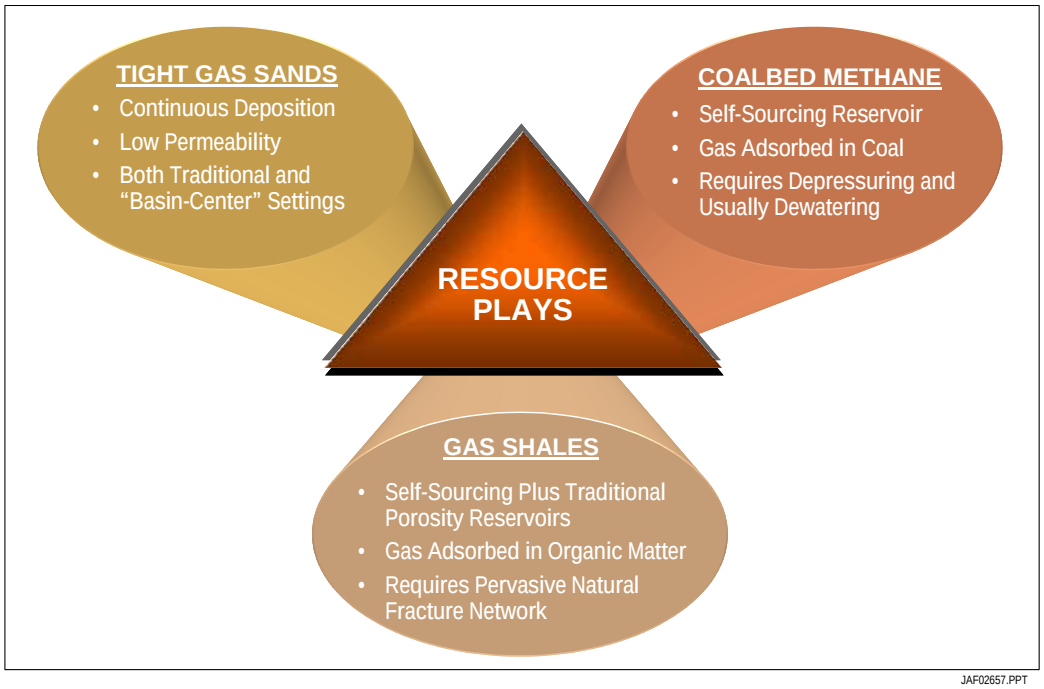

Figure 1. Unconventional Gas and Resource Plays

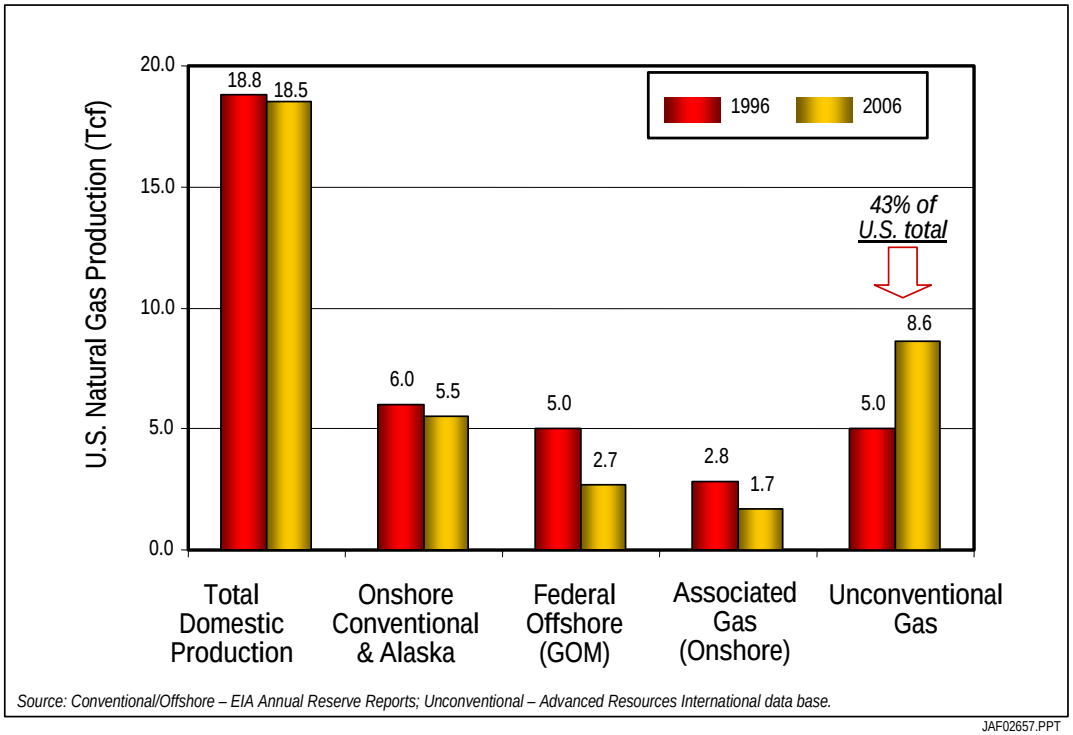

Figure 2. Unconventional Gas Now Accounts For 43% Of U.S. Natural Gas Production

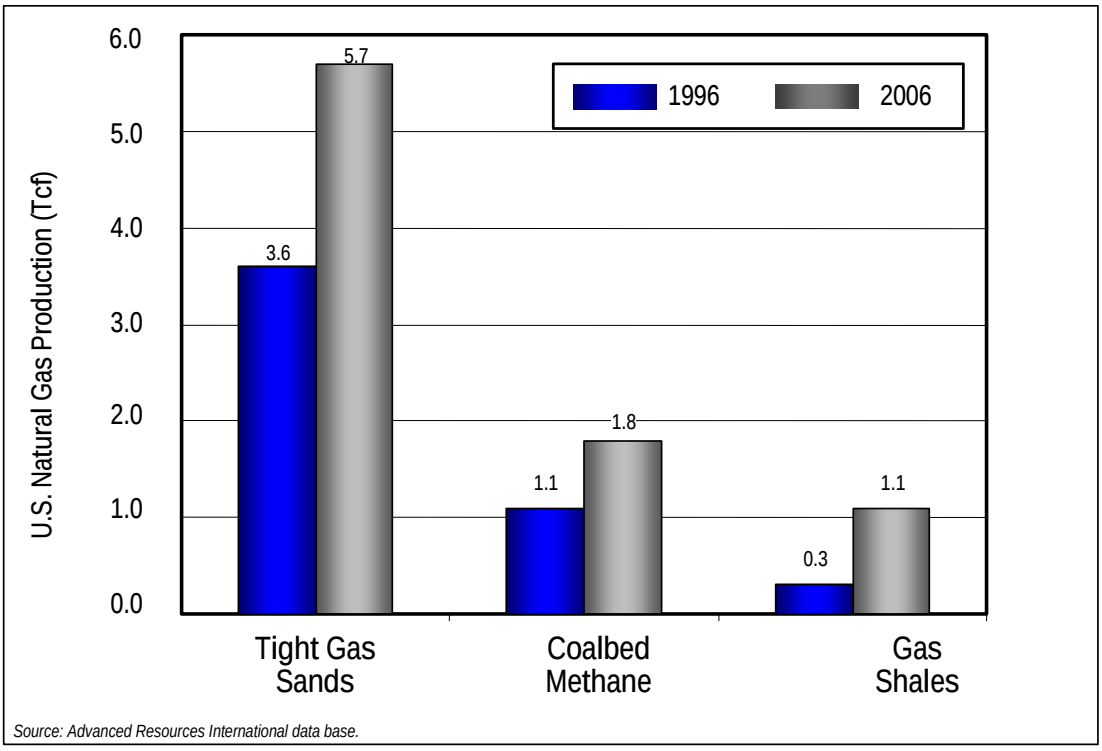

Figure 3. All Three Unconventional Gas Resources Have Seen Production Growth

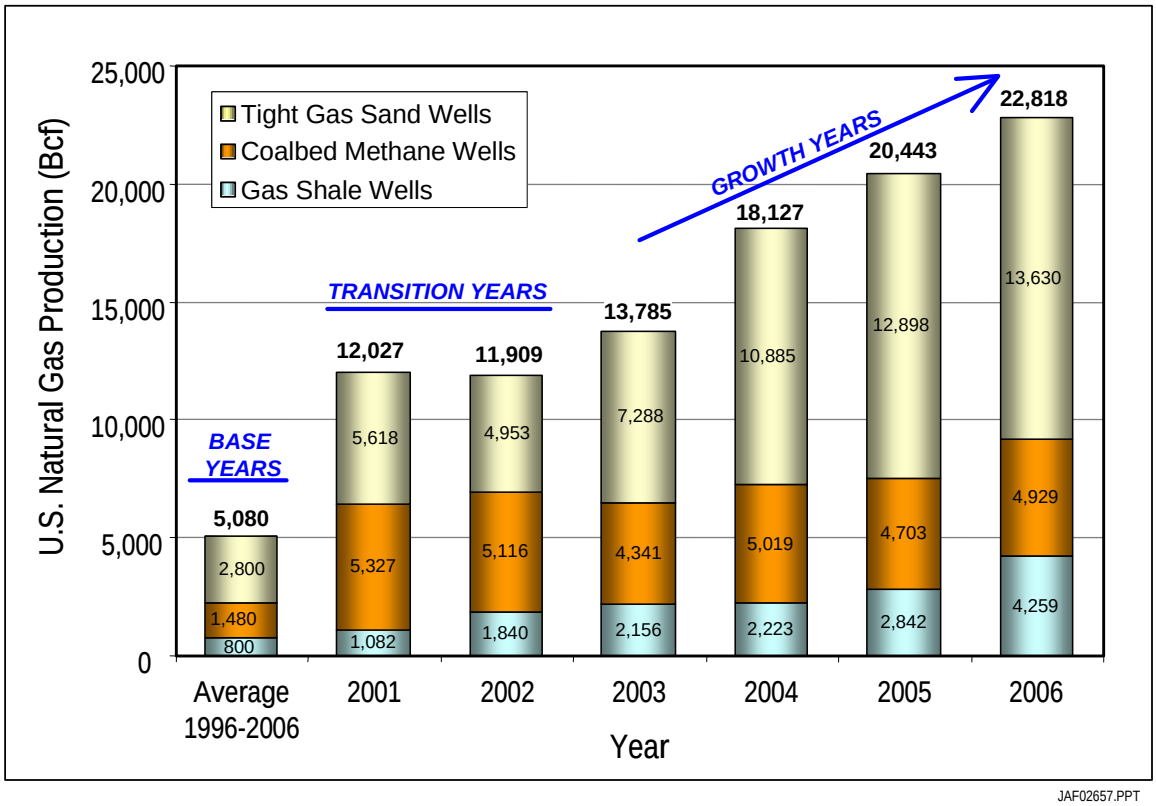

Figure 4. New Unconventional Gas Wells Drilled and Placed On Production

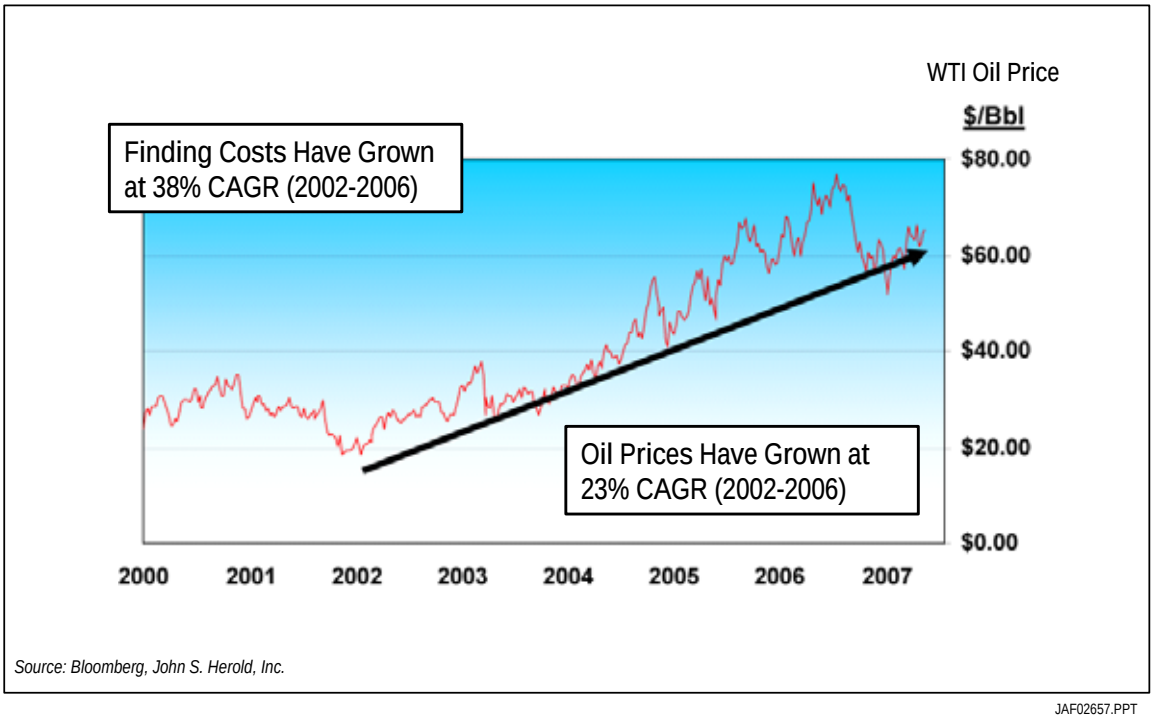

Figure 5. Finding Costs Have Increased Much Faster Than Oil Prices

Table 1. Changes in Unconventional Gas Well Productivity (1996-2005)

Time Period	Tight Gas Sands			Coalbed Methane			Gas Shales		
	Wells*	Reserve Adds (Tcf)	Well Productivity (Bcf/Well)	Wells*	Reserve Adds (Tcf)	Well Productivity (Bcf/Well)	Wells*	Reserve Adds (Tcf)	Well Productivity (Bcf/Well)
'96-'00	14,000	31.5	2.25	7,320	11.6	1.58	4,110	5.2	1.25
'01-'02	10,570	19.5	1.84	10,450	5.7	0.55	3,640	2.8	0.76
'03-'05	31,080	30.1	0.99	14,830	6.6	0.47	14,990	6.7	0.93

*Successful Wells

Table 2. Declines In Gulf Of Mexico Natural Gas Proved Reserves And Production (2000-2005)

	GOM Shelf		GOM Slope	
	Proved Reserves* (Tcf)	Gas Production* (Bcfd)	Proved Reserves* (Tcf)	Gas Production* (Bcfd)
2000 (Beginning of Year)	18.3	10.2	7.7	3.3
2005 (End of Year)	9.4	5.2	8.0	2.9
Change 2000-2005	-8.9	-5.0	+0.3	-0.4

References

U.S. DOE, Energy Information Administration, "U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves 2005 Annual Report", DOE/EIA-0216(2005), November, 2006

Southwestern Energy Company, June 2007 Update, using data from Bloomberg and John S. Herold, Inc.

The Author

Mr. Vello A. Kuuskraa is President of Advanced Resources International with over 30 years of experience in the oil and gas industry, particularly unconventional oil and gas resources, enhanced oil recovery and CO2 sequestration. He has a B.S. in Applied Mathematics from North Carolina State University and an MBA from the Wharton Graduate School, University of Pennsylvania. He serves on the Board of Directors of Southwestern Energy Company.