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Growing and Indispensable: The Contribution of Production from Tight-gas Sands to U.S. Gas Production

Richard Nehring

Nehring Associates, Colorado Springs, Colorado, U.S.A.

ABSTRACT

Production from tight-gas sands has been a growing and indispensable component of U.S. gas production. This chapter discusses three dimensions of the contribution from tight-gas sands to national gas production from 1990 to 2005: (1) within the context of total U.S. gas production, (2) by comparison to other unconventional sources of domestic gas production, and (3) the geographical distribution and geological composition of tight-gas sands production. It concludes with a forecast of future tight-sandstone gas production.

For this analysis, tight-sandstone reservoirs are defined as those commonly considered to be tight, that is, low-permeability sandstone reservoirs that require massive hydraulic fracturing to produce in commercial quantities. Thirty-four plays were identified in the contiguous 48 states as tight-sandstone gas plays.

From 1990 to 2005, gas production in the contiguous 48 states grew from 16.9 to 18.0 tcf. This overall growth was possible only because of growth in unconventional gas production from 2.8 to 8.9 tcf (16.6% in 1990 to 49.5% of national production in 2005). Tight sandstones were the most important source of this unconventional production, reaching 4.34 tcf in 2005 (24.1% of national production and 48.8% of unconventional production).

Three geographic areas have provided most tight-sandstone gas production over the past 15 yr: the western Rocky Mountain basins, east Texas and north Louisiana, and south Texas. The western Rocky Mountain basins (42% of tight-sandstone production in 2005) and east Texas and north Louisiana (27% of 2005 production) are the main centers of tight-sandstone production.

Tight-sandstone gas production is concentrated in several crucial (producing at least 500 mmcf/day) and major (200–500 mmcf/day daily production) plays. The 10 crucial plays produced 3.02 tcf in 2005, 69.5% of tight-sandstone gas production. The 11 major plays produced 1.08 tcf in 2005, 25% of production.

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Tight-sandstone gas production should continue to increase to 2010 primarily because of continued increases in production in half of the crucial plays. Production is likely to stabilize in the 5.0–5.5 tcf/yr range from 2010 to 2015. By 2020, tight-sandstone gas production is likely to decline because of the size of the technically and economically recoverable tight-sandstone gas resource.

INTRODUCTION

Production from tight-gas sands has been recognized for more than a decade as an important contributor to U.S. natural-gas production. Unlike other sources of unconventional gas production, such as coalbed methane, deep-water gas, and gas from shales, each of which is regularly reported, the quantitative contributions of tight-gas sands are little reported and, therefore, poorly understood.

The purpose of this chapter is to provide a rigorous quantitative description of the contribution of tight-gas sands to U.S. natural-gas production. It does so by discussing three dimensions of this contribution from 1990 to 2005: (1) within the context of total gas production from the contiguous 48 states, (2) by comparison to the other sources of unconventional gas production, and (3) by its geographical distribution and geological composition. The chapter concludes with a forecast of future tight-sandstone gas production and a discussion of the major factors shaping this production.

METHODOLOGY

Determining gas production from tight sandstones is a task fraught with ambiguity. Unlike most other sources of unconventional gas production, such as coalbed methane and gas from shales (each clearly defined by lithology), very deep gas (clearly defined by reservoir depth), or deep-water gas (clearly defined by water depth), no unambiguous standard exists for defining tight-sandstone gas production.

The basic definition is that tight sandstones are sandstone reservoirs with low matrix permeability. But how low does permeability have to be for a reservoir to qualify as tight? There seems to be general agreement that permeability in the microdarcy range (less than 1 md) is clearly tight. Some also include reservoirs in the very low millidarcy range (1–5 or 1–10 md).

Determinations are further complicated by the recognition that permeability varies substantially across any given tight reservoir. Median and/or mean permeability may clearly be in the microdarcy range, but the better producing zones (the sweet spots) may have permeability well into the low millidarcy range. Reported permeability measurements may also be disproportionately taken from these better producing zones, thus suggesting a conventional low-permeability reservoir when the reality is otherwise.

Sampling bias is not the only problem with reported permeability measurements. Permeability should properly be measured at existing reservoir conditions (primarily initial reservoir pressure). Measuring core permeability improperly, for example, at surface pressure, overstates the relevant reservoir permeability.

Given these ambiguities, this article has adopted a pragmatic attitude toward the problem of definition. Tight-sandstone reservoirs shall be considered as those commonly recognized as tight, whether by Federal Energy Regulatory Commission 15–20 yr ago or by recent articles and presentations. All other reservoirs in plays with unambiguously tight reservoirs with reported average permeabilities of less than 10 md are also included. This standard provides a close working approximation to the definition of Holditch (2006, p. 86), namely, that a tight-gas reservoir is ''a reservoir that cannot be produced at economic flow rates nor recover economic volumes of natural gas unless the well is stimulated by a large hydraulic fracture treatment or produced by use of horizontal wellbores or multilateral wellbores.''

This approach facilitates the analysis greatly. Typically, when one prominent reservoir in any given play is tight, all or almost all of the remaining reservoirs are tight as well. Thus, the task can be simplified to gathering play production histories or the combined production histories of those clearly tight reservoirs within a play. Nationwide, 34 gas plays with production from tight sandstones were identified. Of these plays, the 21 largest are listed in Tables 1 and 2. In 4 of the 34, most notably the Clinton Sandstone play in the Appalachian Basin and the three Pennsylvanian (Cherokee, Granite Wash, and Missourian) plays in the Anadarko Basin, production data by reservoir were either not available or incomplete. This results in tight-sandstone gas production being understated by 1–2% for the contiguous 48 states.

National gas production data are from the annual reports on proved reserves of the Energy Information Administration. The estimates of gas production from tight sandstones and the other unconventional sources of gas production were developed from the reservoir and field gas production data in Nehring Associates, The Significant Oil and Gas Fields of the United States Database, 22nd Updated Version (data through 2005). All gas production data reported here are on a dry basis, that is, after the removal of plant liquids.

Table 1. **The crucial tight-sandstone gas plays of the United States.***

	Play	*Year Became Crucial*	*Highest Production*		*2005 Production (bcf)*
			Year	*Amount (bcf)*	
769	Rio Grande Valley Lobo	1984	1994	462	335
671	Sabine Uplift Cotton Valley	1990	2005	468	468
103	San Juan Mesa Verde	1992	2004	311	302
798	South Texas Downdip Vicksburg	1994	2002	391	237
165	Moxa Arch Mesozoic	1995	1995	215	175
373	Ozona-Val Verde Pennsylvanian	1996	1998	227	222
171	North-central Green River Upper Cretaceous	2001	2005	494	494
672	West Tyler Basin Cotton Valley	2003	2005	265	265
137	Piceance Basin Cretaceous	2004	2005	271	271
679	Sabine Uplift Lower Cretaceous	2004	2005	248	248

**Source: Nehring Associates, The Significant Oil and Gas Fields of the United States Database, 22nd Update Version (data through 2005).*

BASIC TRENDS IN U.S. GAS PRODUCTION

From 1990 to 2001, natural-gas production in the contiguous 48 states grew slowly, albeit somewhat unsteadily, from 16.9 to 19.3 tcf (Figure 1). The average rate of growth in production was slightly more than 1.2%. From 2001 to 2002, production declined more than 2%. Production declined an additional 5% from 2003 to 2005. This latter decline was essentially the result of hurricane damage to pipelines and production facilities, particularly in 2005 from Hurricanes Katrina and Rita.

This relative stability in overall U.S. gas production masks major changes in the composition of production during this period (Figure 1). The biggest change that occurred was the increasing importance of unconventional gas production. From 1990 to 2005, unconventional gas production grew steadily and strongly from 2.81 to 8.90 tcf, an average annual rate of increase just less than 8%. The share of unconventional gas production increased from 16.6% in 1990 to 49.5% in 2005. By 2006, it seems likely that unconventional gas production will provide more than half of gas production in the contiguous 48 state.

Table 2. **The major tight-sandstone gas plays of the United States.***

	Play	*Year Became Major*	*Highest Production*		*2005 Production (bcf)*
			Year	*Amount (bcf)*	
111	San Juan Dakota	Pre-1970	2001	116	103
375	Midland Basin Upper Pennsylvanian slope	1992	1993	87	28
155	Red Desert-Washakie Upper Cretaceous	1993	2002	169	168
475	Deep Anadarko Cherokee Sandstone	1993	2004	119 (E)**	118 (E)
266	West Denver Basin Codell	1994	2005	102	102
681	Tyler Basin Travis Peak	1995	1995	77	44
102	San Juan Pictured Cliffs	1997	2000	79	69
135	Uinta Upper Cretaceous–lower Tertiary	2000	2005	147	147
276	Wattenberg Delta Front Dakota	2003	2003	80	63
669	North Louisiana Salt Basin Cotton Valley	2004	2005	133	133
485	West Anadarko Permo–Penn Granite Wash	2005	2005	107 (E)	107 (E)

**Source: Nehring Associates, The Significant Oil and Gas Fields of the United States Database, 22nd Update Version (date through 2005).*
***(E) indicates production estimated by Nehring Associates.*

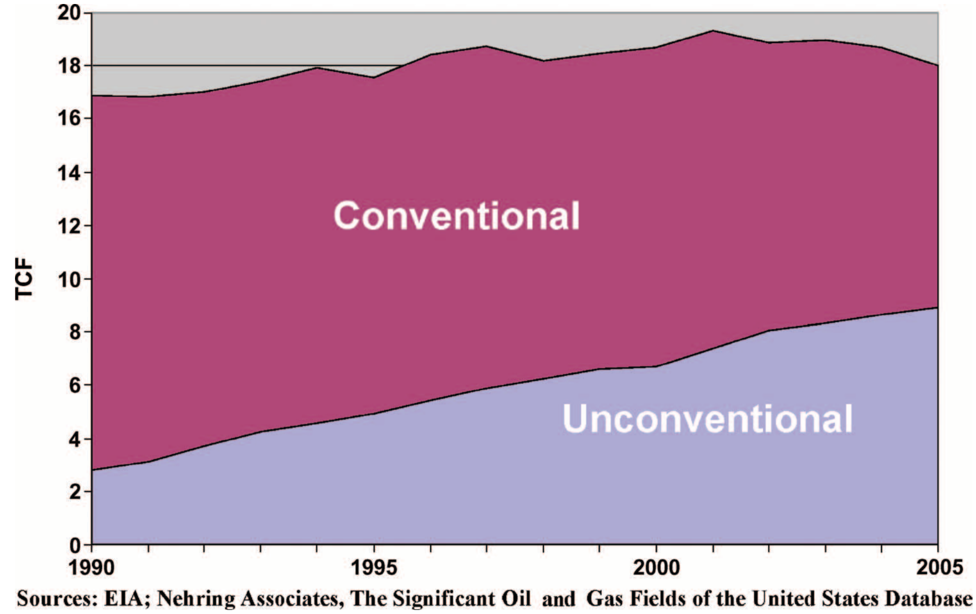

FIGURE 1. Natural-gas (dry) production in the contiguous 48 states by type, 1990–2005. Sources: Energy Information Administration; Nehring Associates, The Significant Oil and Gas Fields of the United States Database.

Simultaneously conventional gas production declined, both absolutely and relatively. Absolutely, conventional production dropped more than 35% from 14.09 tcf in 1990 to 9.09 tcf in 2005. Relatively, its share plummeted from 83.4 to 50.5%. This decline in conventional production underscores the importance of unconventional gas resources. If unconventional production had not grown rapidly, national gas production would have declined from 1990 to 2005.

All the components of unconventional gas production (tight sandstones, coalbed methane, deep water, shales, tight carbonates, and very deep reservoirs) contributed to the growth of unconventional gas production since 1990 (Figure 2). Tight sandstones were, by far, the most important of the unconventional sources. In 2005, tight-sandstone gas production was 4.34 tcf, 48.8% of all unconventional production. In 2005, tight-sandstone gas was providing 24.1% of the U.S. gas production, more than all of the unconventional sources together were providing just 12 yr earlier in 1993.

Tight-sandstone gas production increased by 2.47 tcf from 1990 to 2005, an amount equal to 225% of the total increase in U.S. gas production. However, this healthy increase was only 41% of the total increase in unconventional gas production during these 15 yr. Coalbed methane provided 25%, and deep-water gas provided another 16% of the unconventional increase. (The contribution of deep-water gas promised to be in excess of 20% of the unconventional increase until impaired by hurricanes in 2004 and 2005.) Gas from shales, despite doubling since 2000, contributed only 9% of the unconventional production increase from 1990 to 2005.

Because tight sandstones were the first unconventional source of gas production to become a significant contributor to total U.S. gas production, their relative share of unconventional production declined from 67 to 49% from 1990 to 2005 as other unconventional sources increased rapidly from low levels of production in 1990. (In 1990, tight sandstones provided 11.1% of United States gas production. No other unconventional source exceeded 2% in that year). Tight-sandstone gas production grew an impressive 134% from 1990 to 2005. By comparison, the next two largest sources of unconventional gas, coalbed methane and

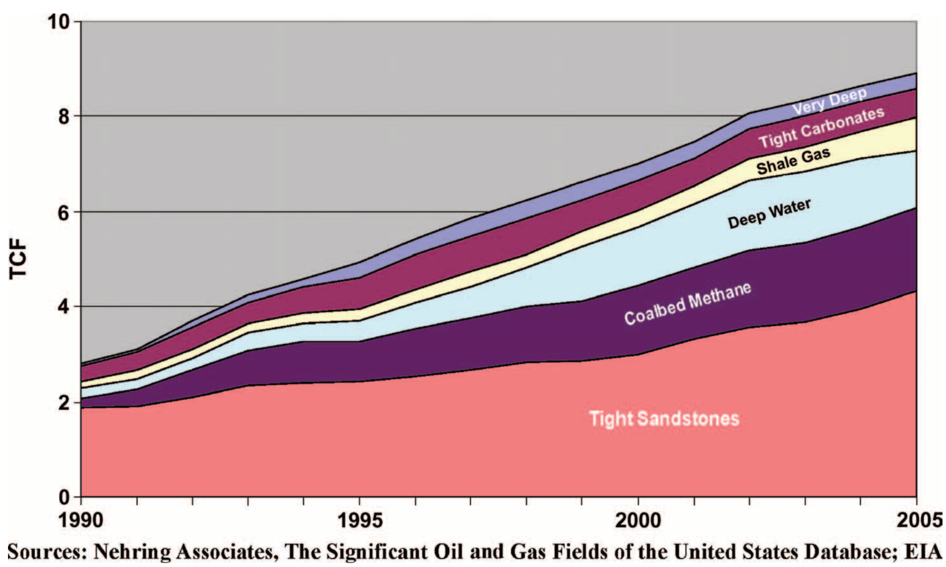

FIGURE 2. The composition of unconventional natural-gas (dry) production in the contiguous 48 states, 1990–2005. Sources: Nehring Associates, The Significant Oil and Gas Fields of the United States Database; Energy Information Administration.

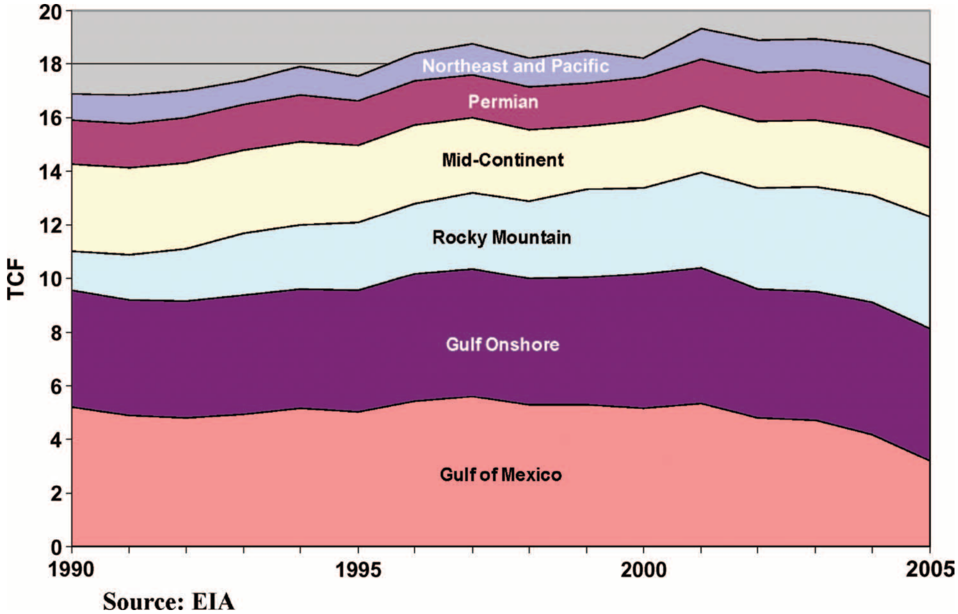

Figure 3. The regional composition of natural-gas (dry) production in the contiguous 48 states, 1990–2005. Source: Energy Information Administration.

deep water, increased 770 and 465%, respectively, during these 15 yr. (Each, however, yielded less than 0.25 tcf in 1990, compared to 1.87 tcf for tight sandstones.)

The increasing importance of unconventional gas to U.S. gas production has changed the regional distribution of U.S. gas production significantly since 1990 (Figure 3). As of 2003, the Gulf of Mexico was no longer the leading source of U.S. gas production. Despite significant growth in both deep water and very deep (Norphlet) production, a 64% decline in conventional gas production (a decline intensified by hurricane damage in 2004 and 2005) has dragged Gulf of Mexico production down to 43% since its peak of 5.58 tcf in 1997. Production in the onshore Gulf Coast, which in 2003 became the leading producing region again for the first time in more than two decades, increased 15% from 1990 to 2005, primarily on the strength of growing tight-sandstone gas production in both east and south Texas and only relatively modest declines in conventional production.

Since 1990, the Rocky Mountain region has vaulted from fifth to second in the regional production rankings and appears likely to resume the lead role by 2010. In the past 15 yr, Rocky Mountain gas production increased 184% (by 2.71 tcf). Growing tight-sandstone and coalbed-methane production provided nearly all of this increase (2.67 tcf or 98.5%). Mid-continent production suffered the largest relative decline, dropping 22% since 1990. The stabilization in mid-continent gas production since 2000 is primarily the result of growing tight-sandstone production from Pennsylvanian plays in the Anadarko Basin. Gas production in the Permian region has grown 18% since 1995 almost entirely because of gas production from the Barnett Shale in the Fort Worth Basin.

The changing regional distribution of U.S. gas production since 1990 underlines the increasing importance of unconventional gas. Where unconventional gas production is growing substantially, regional production grows as well. Where the contribution of unconventional gas is small, regional production declines. Unconventional gas has thus become indispensable to maintaining U.S. gas production.

KEY CHARACTERISTICS OF TIGHT-SANDSTONE GAS PRODUCTION

Two key characteristics dominate the recent history of tight-sandstone gas production in the United States:

1) Tight-sandstone gas production is heavily concentrated in only three geographic areas.
2) Tight-sandstone gas production is highly concentrated in several crucial and major plays.

Three areas have provided most tight-sandstone gas production for the past 15 yr: (1) the western Rocky Mountain basins, (2) east Texas and north Louisiana (ArklaTex), and (3) south Texas (Figure 4). The predominantly Cretaceous reservoirs of most of the western Rocky Mountain basins (San Juan, Uinta, Piceance, greater Green River, and Wind River) form the core area for tight-sandstone gas production in the United States. Between 1990 and 2005, gas production from tight sandstones in these western Rocky Mountain basins increased 225%, providing 51% of the nationwide increase in tight-sandstone gas production. This rapid growth increased the western Rocky Mountain basins share of nationwide tight-sandstone production from 30% in 1990 to 42% in 2005.

Since 1990, tight-sandstone gas production from Upper Jurassic (Cotton Valley) and Lower Cretaceous (Travis Peak and Hosston) reservoirs in east Texas and north Louisiana increased 185%, making this area the second most important center of tight-sandstone production in the United States. Because of the even higher

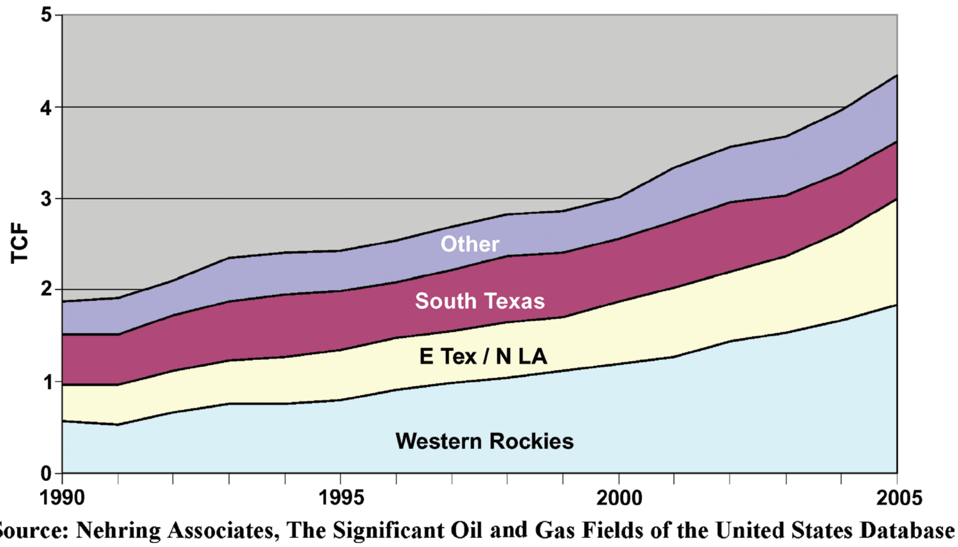

FIGURE 4. The regional distribution of tight-sandstone gas (dry) production in the contiguous 48 states, 1990–2005. Source: Nehring Associates, The Significant Oil and Gas Fields of the United States Database. E Tex/N LA = east Texas and north Louisiana.

rate of growth in tight-sandstone production in the western Rocky Mountain basins, the share of the Arkla-Tex area in total tight-sandstone gas production grew slightly, increasing from only 23% in 1990 to 27% in 2005.

In 1990, the Paleogene (Lobo and Vicksburg) and Upper Cretaceous tight-sandstone reservoirs of south Texas were almost as important a source of tight-sandstone gas production as the western Rocky Mountain basins. Although tight-sandstone production has since grown in south Texas, the rate of growth was so low that the south Texas share of tight-sandstone gas production dropped from 29% in 1990 to 14% in 2005.

No other area has emerged as a significant tight-sandstone gas-producing area since 1990. The Permian region has been a small but steady contributor. Production in the eastern Rocky Mountain basins has more than doubled since 1990, but has done so from a very small base. Rapidly growing tight-sandstone gas production from the Anadarko Basin could make this area a significant contributor to the national totals by 2010.

The other key characteristic of tight-sandstone gas production is its concentration in a relatively small number of crucial and major plays. A play is defined as a set of reservoirs and/or prospects in the same geographical area that have similar geological characteristics. Geologic formation is the primary characteristic used to define a play. Trap type, hydrocarbon type, depositional environment, and pressure regime are other characteristics used to define plays. This analysis uses the play definitions developed by Nehring Associates for use in The Significant Oil and Gas Fields of the United States Database. Their play definitions are similar (and in many cases identical) to the assessment unit definitions used by the U.S. Geological Survey in its latest evaluations of U.S. oil and gas potential.

The distinctions of crucial and major plays used here indicate play size as expressed by annual level of production. Crucial plays are those that produce at least 500 mmcf/day (183 bcf/yr), a level approximately 1% of domestic gas production. Major plays are those that produce between 200 and 500 mmcf/day (73 and 183 bcf/yr).

Currently, 10 crucial tight-sandstone gas plays in the United States exist (Table 1). Together, these 10 plays produced 3.02 tcf in 2005, 16.8% of total U.S. gas production, and 69.5% of tight-sandstone production (Figure 5). Most of these plays have attained crucial status relatively recently, all but one since 1989 and four since 2000. Nearly all are at or near their highest historic production levels. Five of these plays had their highest production ever in 2005. Two others were within 3% of their historic highs. In 2003, the Moxa Arch Mesozoic play dropped below the minimum level of production to continue qualifying as a critical play.

Another 11 tight-sandstone plays reached major production levels between 1990 and 2005 (Table 2). Four of these have subsequently fallen beneath the minimum level for a major producing play. Only six of these plays are still within 10% of their highest historic producing level. In 2005, these 11 major plays produced 1.08 tcf, 25% of tight-sandstone production.

Together, the crucial and major plays dominate tight-sandstone production. In 2005, they provided nearly 95% of tight-sandstone gas production, only a slight drop from the 97% they provided in 1990. The future of tight-sandstone gas production in the United States essentially resides in these plays.

PROGNOSIS

Gas production from tight sandstones should continue to increase through the remainder of the decade. By 2010, production from tight sandstones should

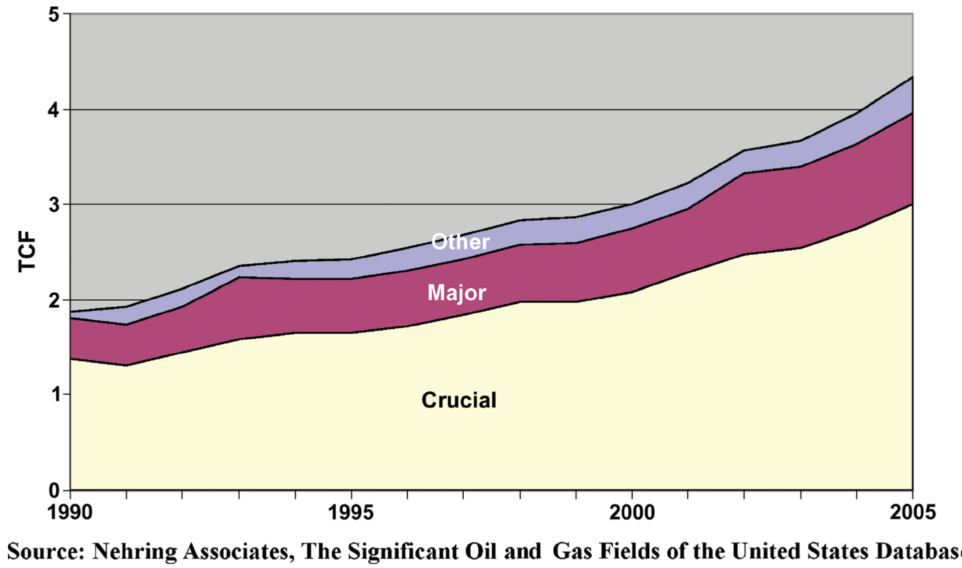

FIGURE 5. The composition by play size of tight-sandstone gas (dry) production in the contiguous 48 states, 1990–2005. Source: Nehring Associates, The Significant Oil and Gas Fields of the United States Database.

be 5.0–5.5 tcf annually, 26–30% of the total contiguous 48-state gas production.

Recent trends in tight-sandstone gas production by play provide strong support for this forecast. Growth in tight-sandstone production overall depends on continued production growth in the crucial and major plays and/or the emergence of new crucial and major plays.

Production in each of the five crucial plays that reached their highest levels of historic production in 2005 (the North-central Green River Upper Cretaceous [Jonah and Pinedale fields]; the Sabine Uplift Cotton Valley; the Piceance Basin Cretaceous; the West Tyler Basin Cotton Valley; and the Sabine Uplift Lower Cretaceous) should continue to grow over the next several years. All have substantial resource potential; all have considerable proved undeveloped reserves; and all are continuing to experience major drilling programs. (Together, these five plays provided 40% of 2005 tight-sandstone gas production.)

Production in four of the other crucial plays (Rio Grand Valley Lobo, San Juan Mesa Verde, Ozona-Val Verde Pennsylvanian, and Moxa Arch Mesozoic) should, at worst, continue to decline slightly from 2005 to 2010. The South Texas Downdip Vicksburg play, the only crucial tight-sandstone play that requires major new discoveries to sustain production, will most likely continue its recent declines. (This is not only a tight-sandstone play; it is also an ultra-high-pressure and ultra-high-temperature play, conditions that place major technological and economic constraints on its exploration and development.)

Two of the major plays, the Red Desert-Washakie Upper Cretaceous and the Uinta Upper Cretaceous–lower Tertiary, should become crucial plays by 2010. A third play, the Western Anadarko Permo–Penn Granite Wash, is also a potential crucial play. Except for the Deep Anadarko Cherokee Sandstone, the San Juan Dakota, and West Denver Basin Codell plays, each of which should at least maintain recent production levels, the remaining major tight-sandstone gas plays seem likely to decline during the remainder of the current decade. Of the 13 nonmajor tight-sandstone gas plays, at best, only two, the Northern Wind River Lower Tertiary and the Northwest Anadarko Missourian Sandstone, have any possibility of reaching major play status by 2010. None of these 13 smaller plays exhibit the recent rapid production growth or have the resource potential associated with the plays that have recently attained major or crucial status.

From 2010 to 2015, gas production from tight sandstones is likely to stabilize. By 2020, it should be declining. This reversal of the growing trend of more than two decades in tight-sandstone gas production originates primarily from the likely size of the technically and economically recoverable tight-sandstone gas resource.

As of 2005, cumulative production of natural gas from tight-sandstone gas reservoirs was approximately 85 tcf. Proved reserves, both developed and undeveloped, were approximately 60 tcf. Committed tight-sandstone gas resources (the sum of cumulative production and proved reserves) were thus 145 tcf. The Rocky Mountain basins, with 71 tcf, accounted for nearly half of this committed reserve.

From 2006 to 2015, another 50 tcf of gas from tight-sandstone reservoirs is likely to be produced. Cumulative production by 2015 should thus approximate 135 tcf. Assuming 2015 annual production in the 5.0–5.5-tcf range, proved reserves by then should be 50–60 tcf. Committed resources of tight-sandstone gas would thus be in the 185–195-tcf range.

The future of tight-sandstone gas production will depend on the size of the ultimate tight-sandstone recoverable gas resource. The recent gas resource assessments by the U.S. Geological Survey for the Rocky Mountain basins suggest a continuous tight-sandstone mean resource potential as of the end of 2000 of approximately 85 tcf. From 2001 to 2005, 22 tcf was added to committed resources (known recovery) in the Rocky

Mountain basins, leaving a remaining potential resource of 63 tcf. Assuming that the Rocky Mountain basins have 50–60% of the remaining tight-sandstone potential (the U.S. Geological Survey has yet to complete and/or publish its assessments for other key tight-sandstone basins), the potential resource as of 2005 is 105–125 tcf. This suggests an ultimate tight-sandstone gas resource of 250–270 tcf.

Peak annual production rates of oil and gas resources are typically reached at or somewhat preceding the midpoint of ultimate production. If this historic relationship holds for tight-sandstone gas production, production should peak between 2010 and 2015. Cumulative production should reach 125 tcf by 2013 and 135 tcf by 2015.

The ultimate tight-sandstone gas resource could be substantially higher than the 250–270 tcf indicated earlier. The in-place tight-sandstone gas resource is thought to be massive. Just how massive is a subject of some debate, involving such questions as source rock capability, reservoir capacity, and data adequacy. Estimated recovery factors thus tend to be quite low (not only relative to conventional gas reservoirs, but even compared to oil reservoirs). Higher sustained prices (in excess of $10.00–12.00/mcf) after 2010 and improved completion and stimulation technology would promote continued well downspacing to 20, 10, or even 5 ac (8, 4, or even 2 ha) per well. Because these wells would likely have both lower reserves per well and lower production per well, their effects on tight-sandstone gas production will most likely be to lengthen the period of peak production (creating more of a plateau instead of a peak) and/or reduce the decline rate of production.

Tight-sandstone gas production has been and is both a growing and indispensable component of U.S. natural-gas production. Its growing importance for national production is likely to come to an end early in the next decade. However, it will remain an indispensable part of U.S. production for several decades to come.

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