

A Comparison of the PGC and NPC Tight Gas Estimates

A major problem with estimating the natural gas resource from unconventional reservoirs is determining how much of this unconventional gas has already been included in estimates of the conventional resource. The primary areas of overlap would be the tight sands and Devonian shales. Much of the tight sands represents the lower end of a continuum of gas-producing reservoirs. Except for its lower porosities and permeabilities, the "blanket" portion of the tight sands resource is quite similar in other respects to conventional formations and, in fact, gas is presently being produced from tight blanket formations and even, in some cases, from lenticular formations. The Devonian shales have been producing gas since the early days of petroleum development in this country. Obviously, these categories cannot be considered entirely new additions to the resource base.

There is no clear-cut boundary between gas that has been included in conventional resource estimates and that which has not. The cutoff point for the conventional resource varies from assessment to assessment and tends to be loosely defined on the basis of rather ill-defined economic and technical constraints. For example, the Potential Gas Committee (PGC) defines its resource estimate to include gas from "all wells which would be drilled in the future under assumed conditions of adequate economic incentives in terms of price/cost relationships and current or foreseeable technology."¹

The PGC assessment, *Potential Supply of Natural Gas in the United States*, is one estimate of the conventional resource which overlaps with the "unconventional." Given its broad definition of what constitutes the undiscovered recoverable resource, the PGC chose not to define a physical cutoff point, such as a permeability limit, to separate out tight gas from conventional gas. To do so would exclude from the resource base gas that conceivably could be produced under the assumptions of reasonable price and technology. Thus, the PGC has consistently designated some "tight" gas as part of the conventional resource.

Recently, the PGC has made an attempt to determine the percent of its total resource estimate that occurs in tight formations. (It includes in the tight gas category both tight sands and Devonian shales.) For

each of its reporting areas (fig. C-1 (a)), it estimates the percentage of gas that occurs in tight formations, above and below 15,000 ft. Table C-1 gives the PGC estimates, in TCF, for each reporting area.² The total tight gas included in these estimates is 172 TCF, or 20 percent of the total potential resource.

The following analysis compares the PGC tight gas breakout with the National Petroleum Council's (NPC) estimates of tight sands and Devonian shale resources. It has been suggested that there may be a considerable amount of overlap between these two estimates. Because estimates of the United States' gas resource base and future supply often add conventional and unconventional gas contributions, elimination of any overlap would decrease the projected total resource base and supply. Additionally, since an overlap is most likely to occur among the most attractive gas prospects, elimination of the overlap may affect near- and mid-term supply forecasts disproportionately.

In order to compare the PGC breakout with the NPC estimates, the assumptions underlying the estimates need to be reviewed. Some of the assumptions are documented, others have been confirmed through personal communications.

The definition for tight gas used by the PGC is similar to the FERC definition and includes all gas in formations with average permeabilities less than 0.1 millidarcy (red). The NPC report does include some gas in formations with average permeabilities greater than 0.1 md, but the amount is small, less than 1 trillion cubic feet (TCF). Therefore, the permeability levels for the two estimates are generally compatible.

Not all the gas in the PGC tight gas estimate will overlap the NPC estimate. For example, PGC tight gas includes gas from new pools and reservoirs in formations that are already being produced. By definition, this gas is mostly accounted for in the probable category.⁴ The NPC report specifically **excludes areas already producing tight gas from its evaluation, since its objective is to estimate "new potential reserve additions."** Thus, tight gas in the PGC probable category, amounting to some 56 TCF, cannot be part of any overlap between the two estimates.

The NPC report does not include any potential gas resources in formations at depths greater than 15,000 ft, although it postulates that a significant additional

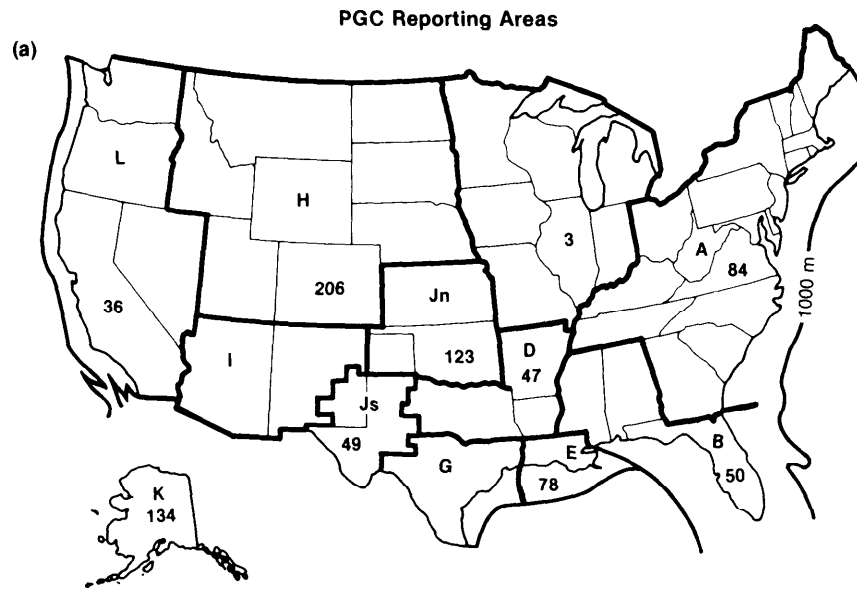
¹ Potential Gas Agency, *Potential Supply of Natural Gas in the United States* (as of Dec. 31, 1980), 1981.

²Based on the 1982 revised figures for the total resource: Potential Gas Agency news release, February 1983.

³National Petroleum Council, *Unconventional Gas Sources*, 1980.

⁴Harry Kent, Director, Potential Gas Agency, personal communication, 1984.

Figure C-1.—PGC and NPC Reporting Areas



NOTE: From Figure 1—Reporting areas and total potential gas supply. 1982 Potential Gas Committee

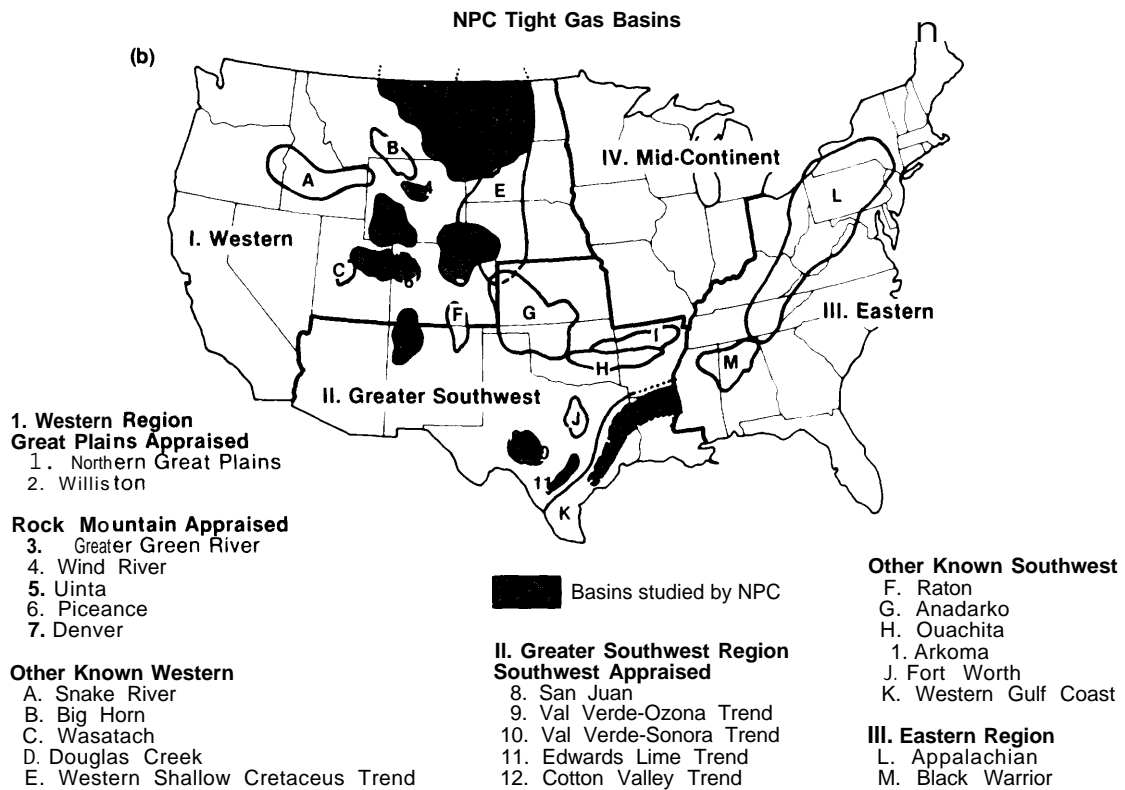


Table C.1.—PGC Estimate of Gas Occurring in Tight Formations Included in Its 1982 Estimate of Total U.S. Undiscovered Recoverable Resources (in TCF)

PGC area	Probable		Possible		Speculative		Total
	<15,000	>15,000	<15,000	>15,000	<15,000	>15,000	
A	23.49	—	0.4	—	—	—	23.89
B	0.32	0.18	0.24	0.3	0.3	0.48	1.82
C	—	—	—	—	—	—	—
D	0.8	—	3.0	—	3.0	0.8	7.6
E	—	—	—	—	—	—	—
G	0.28	0.3	0.54	0.48	0.12	0.16	1.88
H	21.75	5	14.43	14.56	7.02	29.2	91.96
I	0.94	—	0.33	—	—	—	1.27
Jn"	—	1.98	—	14.06	3	20.06	40.2
Js	0.49	—	0.38	—	—	—	0.87
L	0.04	0.3	0.3	0.6	0.7	0.4	2.34
Total	55.87		50.72		65.24		171.83

SOURCE: Potential Gas Agency. *Potential Supply of Natural Gas in the United States (as of Dec 31, 1982)*, Report of the Potential Gas Committee, Colorado School of Mines, June 1983.

resource could exist at these depths. However, over half of the PGC tight sands estimate is found at greater than 15,000 ft depths—89 TCF total, 81 TCF in the possible and speculative categories. We assume that there is no overlap between the PGC tight gas below 15,000 ft and the NPC estimate.

The gas projected by the NPC to be recoverable from tight sands at \$5.00/MCF,⁵ with a 15 percent discounted cash flow rate of return (DCF ROR) and using base technology, is assumed to represent a reasonable upper economic limit to gas that might be included in the PGC estimate⁶ (the NPC's "maximum recoverable" gas would be an extreme upper limit). In other words, tight gas considered produceable at less than \$5.00/MCF using present technology is likely to be included in the PGC tight gas estimate.

In summary, the most potential for overlap exists between the PGC tight gas in the possible and speculative categories at less than 15,000 ft and the NPC tight sands and Devonian shales gas recoverable at \$5.00/MCF (1979\$) using base technology. This is graphically represented in figure C-2. It should be noted that the overlap determined by a straightforward comparison using the above assumptions may be too large. PGC used FERC criteria as a guide to defining the tight formations and the FERC interpretation of what constitutes tight gas has tended to be generous relative to the NPC interpretation.

Other specific assumptions need to be made to compare individual areas. These are discussed in more detail below.

Areas of Overlap

The PGC reporting areas and the NPC appraised and extrapolated basins are shown in figure C-1 (a) and (b), respectively. Table C-2 lists the comparable areas and notes where the PGC has specifically identified tight gas included in the potential resource. The total PGC estimate of gas in tight formations is about 172 out of a total of 870 TCF, or approximately **20 percent of the remaining undiscovered recoverable resource**. NPC estimates 607 TCF of recoverable gas from tight sands⁸ and an additional 25 TCF, at least, from Devonian shales. Our comparison attempts to determine how much of this 633 TCF of gas has already been included in the PGC estimate of conventional undiscovered resources and cannot be considered as additions to the U.S. resource base.

Our analysis indicates that the greatest potential for overlap occurs in the Rocky Mountain region covered by the PGC reporting area H (fig. C-1 (a)). The comparable NPC area is the Rocky Mountain Basins plus the Northern Great Plains (fig. C-1 (b)). This area is already the site of considerable production of gas from tight formations (e.g., from the Wattenberg field of the Denver Basin). The extent of the duplication is summarized in table C-3.

For a first approximation, we assume that the PGC tight gas does not include gas from the Northern Great Plains.⁹ Basins that probably are included in both Rocky Mountain estimates are the Greater Green River, Uinta, Piceance, Wind River, and Denver basins. Within these basins, the most likely overlap occurs between the blanket formations of the NPC re-

⁵For simplicity, the NPC prices (in 1979 dollars) are used in this analysis.

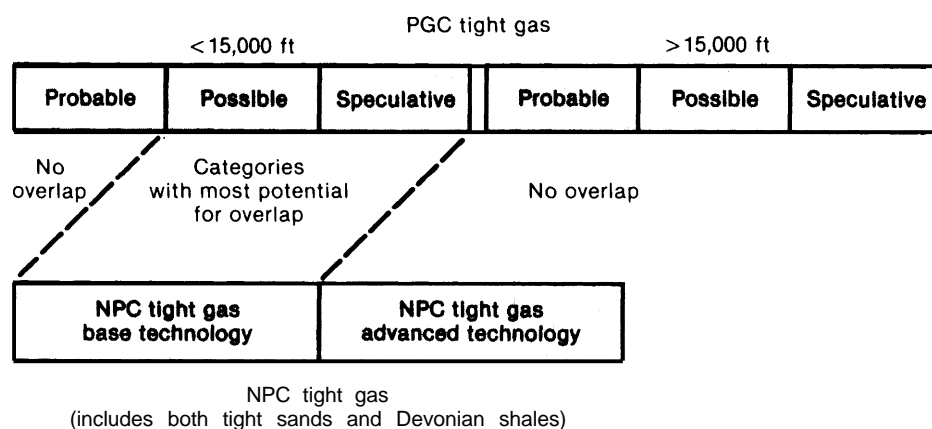
⁶The "boundary conditions" for the PGC resource estimate are imprecise, and no limit on price is specified other than what may be inferred from the phrase "adequate economic incentives in terms of price/cost relationships."

⁷To be precise, the NPC definition of its "base case" technology allows evolutionary improvements in presently available technology.

⁸This is the "maximum recoverable" gas. Using present technology, NPC estimates that 365 TCF would be recoverable at \$5.00/MMBtu.

⁹Kent, op. cit.

Figure C-2.—PGC and NPC Categories of Tight Gas



SOURCE: Office of Technology Assessment.

Table C.2.—Comparable Areas—PGC Report and NPC Report

PGC reporting areas	Comments	NPC basins
Area A.	Includes some Devonian shales recoverable by normal drilling, well stimulation, and completion and analogous in geologic setting to previous production	Appalachian Basin Devonian shales Eastern extrapolated tight sands
Area B.	—	Eastern extrapolated tight sands
Area D.	Includes tight formations of Travis Peak and Cotton Valley	Cotton Valley appraised, Southwest extrapolated (east)
Area G.	—	Edwards Lime Trend, Southwest extrapolated (south)
Area H.	Includes tight formations of Greater Green River, Uinta, Piceance, and Wind River	Rocky Mountains appraised, Northern Great Plains appraised, Western extrapolated
Area I.	—	San Juan appraised, Southwest extrapolated (west)
Area J north.	—	Southwest extrapolated (east)
Area J south.	—	Val Verde Ozona-Sonora appraised, Southwest extrapolated (central)

SOURCE: Office of Technology Assessment

Table C-3.—Comparison of PGC and NPC Tight Gas Resource, Rocky Mountain Region (in TCF)

NPC Rocky Mountain Basins ^a	Recoverable \$5.00/McFb	Maximum recoverable	PGC area H <15,000 ft	Tight gas	Percent overlap
Blanket.	19.7	34.5	Probable Possible Speculative	21.75 14.43 7.02)	None 62-100
Lenticular.	68.9	164.9			None
Combined.	12.6	15.5			None
Total.	101.2	214.9	Total	43.20	10-21

^aIncludes: appraised Greater Green River, Uinta, Piceance, and Denver basins, and other Western *extrapolated* basins.^bGas recoverable at \$500/MCF (1979\$), 1570 DCF ROR, assuming base technology.

SOURCE: Office of Technology Assessment

port and the PGC possible and speculative categories at depths less than 15,000 ft. We are assuming that the PGC estimate does not include any gas in lenticular formations or in combined blanket and lenticular formations. This assumption may not be strictly correct because individual lenses have been produced in past drilling by directly intersecting the lens with the wellbore. There is no existing technology, however, for producing lenses remote from the well bore.

Much of the Rocky Mountain gas occurring in blanket formations appears to be included in both the NPC and PGC estimates. The NPC estimated range of gas recoverable in blanket formations, from gas available at \$5.00/MCF, 15 percent DCF ROR, and base technology, to the maximum recoverable gas, is **20 to 34 TCF** (see vol. V, table 9 of the NPC report). This includes 7 to 10 TCF in extrapolated blanket formations in this region. The NPC estimate for gas in blanket formations is very close to the PGC estimate of 21 TCF of possible and speculative gas occurring in tight formations at less than 15,000 ft, and probably represents a duplication of the PGC estimate.

Another significant area of overlap may occur in the Cotton Valley Trend of east Texas and Louisiana. This area is included in PGC area D and is one of the appraised basins of the NPC report. The NPC range of gas in the Cotton Valley, from \$5.00 to the maximum recoverable, is 7 to 12 TCF, which probably overlaps the 6 TCF of possible and speculative tight gas in formations less than 15,000 ft as estimated by the PGC.

In south Texas, the NPC estimate ranges from **44 (at \$5.00) to 60 TCF (maximum recoverable)**. The estimate covers extrapolated formations as well as the appraised Edwards Lime Trend, with an estimated gas potential between 6 TCF (at \$5.00) and 9 TCF (maximum recoverable). It is also covered by PGC reporting area G. Here, PGC estimates 0.66 TCF of gas in the possible and speculative categories above 15,000 ft. It is likely that the PGC estimate, even if it does not specifically refer to the Edwards Lime Trend, is duplicated somewhere in the NPC appraised plus extrapolated formations.

In the PGC's area 1, including the San Juan Basin, most of their estimated tight sands gas is derived from infill drilling of the Dakota and Mesaverde formations and is most likely included in its probable category. The 0.33 TCF remaining in the possible category may be new gas occurring in these formations, and most or all of it may overlap the NPC estimates of 1.49 to 2.31 TCF for the appraised San Juan Basin. Although the NPC extrapolates an additional 11 to 16 TCF in this region (which would include gas in the Raton Basin in northeastern New Mexico), the PGC estimate probably does not overlap with any extrapolated gas.

A large quantity of gas—40 TCF—is estimated by the PGC to occur in tight formations within its reporting area Jn. Most of this gas is thought to be found in the Deep Anadarko and Springer sands. Thirty-six TCF are found at depths greater than 15,000 ft. This leaves only 4.1 TCF in the possible and speculative categories above 15,000 ft to potentially overlap the NPC tight gas. All the NPC basin estimates in this region are extrapolations with a total range from 16 to 24 TCF. It is likely, but not conclusive, that the 4.1 TCF of PGC gas does overlap NPC gas.

The amount of overlap in tight formations in the Eastern United States is more difficult to determine. This area encompasses reporting areas A and B of the PGC report and the Eastern U.S. extrapolated tight sands and the Appalachian Basin Devonian shale of the NPC report. In area A, excluding the estimated probable gas, which is likely to be primarily gas from producing formations in Devonian shales and inter-layered sandstones, leaves 0.4 TCF in the possible category. In area B, there are 0.54 TCF in the possible and speculative categories at depths less than 15,000 ft.

Producible gas from Devonian shales as estimated by the NPC falls in the range of 12 TCF at \$5.00/MCF and 25 TCF maximum recoverable using traditional technologies only. The extrapolated tight sands resource for the Eastern United States ranges from 72 to 101 TCF. In OTA's opinion, the 0.94 TCF of gas in the PGC areas A and B are likely to be included somewhere in the total of the NPC extrapolated tight sands and the Devonian shale resource.

Table C-4 summarizes the total overlap between NPC and PGC estimates, amounting to approximately 30.5 TCF. The percent reduction due to duplication for the total NPC tight gas resource (including both tight sands and Devonian shales) is 8 percent for the gas recoverable at \$5.00 and 5 percent for the maximum recoverable gas.

The amount of overlap, then, is not vitally important in terms of reducing the size of the total additional resource from unconventional reservoirs. More important are the specific areas of overlap, since these oc-

Table C-4.—Overlap of PGC and NPC Resource Estimates

PGC total tight gas	NPC total recoverable gas tight sands and Devonian shales		Total overlap
	At \$5.00*	Maximum	
171.83 TCF	376.6 TCF	633.5 TCF	30.5 TCF

*Gas recoverable at \$5.00/MCF (1979\$), 15% DCF ROR, assuming base technology.

SOURCE: Office of Technology Assessment

cur in areas which have been predicted to be main contributors to supply in the next **20 years**.

For example, the NPC estimates that the Rocky Mountain Basins will contribute over 14 TCF to production over the next 20 years and 43 TCF to reserve additions, according to its standard development scenario. It is likely that much of this production will be from the blanket formations, as these are generally the more profitable prospects. However, if these formations are already partially counted in conventional resource estimates, and these estimates are used in forecasting supply, what the NPC is estimating cannot be considered as additions to existing projections of future conventional supply.

Another primary contributor to the NPC reserve addition and supply forecasts in the next 20 years is the Greater Southwest, including primarily the Cotton Valley, the Val Verde Ozona-Sonora Trend and the Edwards Lime Trend. The Cotton Valley Trend potential, however, appears to be duplicated in the PGC report; thus it, also, cannot contribute additional reserves or supply.

This analysis deals only with the overlap between the PGC and the NPC assessments of the natural gas resource. Similar duplication is likely to exist in other geologically based estimates such as the U.S. Geologic

Survey's (USGS) estimate of undiscovered recoverable gas resources.¹⁰ However, because of varying approaches to estimating the resource, no categorical statement of the amount of overlap between conventional and unconventional resource estimates can be made.

A final comment needs to be made regarding the PGC estimates of tight gas recoverable from formations at depths greater than 15,000 ft. This gas represents a resource additional to the NPC estimated tight sands resource. In general, these resources would be considered even less economic to produce than the NPC gas because of the higher costs and greater technical difficulty of drilling and fracturing at these depths. However, Potential Gas Committee members felt that the technology did exist to produce tight gas from deep formations, and under certain conditions there might be sufficient incentive to produce this gas. Nevertheless, we feel that the 89 TCF of deep tight gas in the PGC estimate should be regarded with at least as much, if not more, caution than the NPC estimates in terms of evaluating their potential for contributing to near- and mid-term supply.

¹⁰G.L. Dolton et al., *Estimates of Undiscovered Recoverable Conventional Resources of Oil and Gas in the United States*, U.S. Geological Survey Circular 860, 1981.