The 1995 National Assessment of United States Oil and Gas Resources: The Economic Component

Introduction

The 1995 National Assessment of United States Oil and Gas Resources prepared by the U.S. Geological Survey (USGS) provides estimates of quantities of technically recoverable oil and natural gas that could be added to our already proved reserves in the onshore and State offshore areas of the United States. These areas presently contain 85 percent of U.S. proved reserves and account for 80 percent of domestic hydrocarbon production. Proved reserves are known resources that can be recovered profitably with existing technology. The estimates of yet-undiscovered recoverable resources were reported in USGS Circular 1118 (U.S. Geological Survey, National Oil and Gas Resource Assessment Team, 1995) and in Digital Data Series DDS-30, release 2 (Gautier and others, 1996); they are based on detailed geologic analysis constrained by a thorough understanding of what is producible with current technology.

The estimates are reported as ranges with different levels of confidence. The oil and gas volumes in figure 1 are mean values; actual volumes will vary from these numbers.

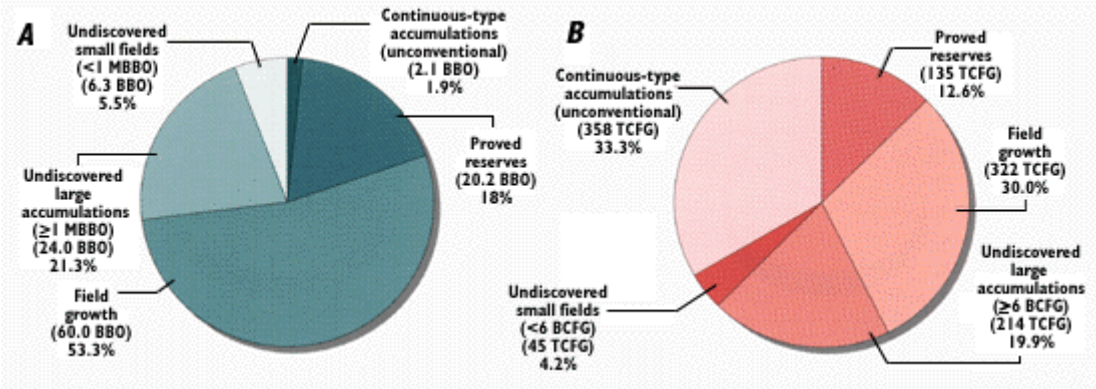

Figure 1. Technically recoverable oil and gas resources of the United States, exclusive of Federal offshore resources. A, Oil. BBO, billions of barrels of oil; MMBO, millions of barrels of oil. B, Gas. TCFG, trillions of cubic feet of gas; BCFG, billions of cubic feet of gas.

The Economic Component

The USGS 1995 national assessment reported on three main categories of hydrocarbon resource in addition to proved reserves:

- Undiscovered conventional

An economic dimension to the geology-based resource estimates in the USGS 1995 national assessment is provided by USGS Circular 1145 (Attanasi, 1998). Specifically, this economic analysis estimates the cost of transforming technically recoverable resources (as reported in the assessment) into producible proved reserves -- it shows the price that would have to be paid to find, develop, and produce any particular quantity of assessed resource

accumulations - the traditional resources sought by the oil and gas industry, including those resources that are postulated to exist outside of known fields or accumulations and that, if found, could be extracted by using traditional development practices.

- Unconventional resources in continuous-type accumulations - defined to include those oil and gas resources that exist as geographically extensive accumulations in coals (as coal-bed gas), sandstones, and shales outside of discrete well-defined conventional traps.
- Field growth (called "inferred reserves" in the assessment) - the resources expected to be added to reserves in known fields through field extension, revision of reserve estimates, addition of new pools, and application of new recovery techniques in the next 80 years.

with current technology and existing scientific understanding. The economic analysis is intended to place the geologic resource assessment into a context more easily understood by industry and government policymakers.

Figures 2 and 3 summarize findings of the economic analysis. The black curves in figures 2 and 3 show incremental costs of finding, developing, and producing oil and gas from undiscovered conventional fields. The red curves in figures 2 and 3 show the incremental costs of obtaining the total volumes of oil and gas that might be made available from both conventional and selected unconventional oil and gas accumulations - the distance between the black and red curves at a given price thus represents the volume that could come from selected unconventional sources. Incremental cost functions show at each price level the volumes of hydrocarbons the industry is capable of adding to proved reserves and producing rather than predicting what industry will actually supply.

Table 1 presents regional data from the economic analysis. It shows volumes of oil and gas that could be available at $18 per barrel for oil and $2 per thousand cubic feet (mcf) of gas and, similarly, volumes with incremental costs of $30 per barrel of oil and $3.34 per mcf of gas from the assessed undiscovered conventional and unconventional resources. Economic oil anticipated in future discoveries is distributed mainly among five regions -- Alaska, the Pacific Coast, the Rocky Mountains and Northern Great Plains, West Texas and Eastern New Mexico, and the Gulf Coast.

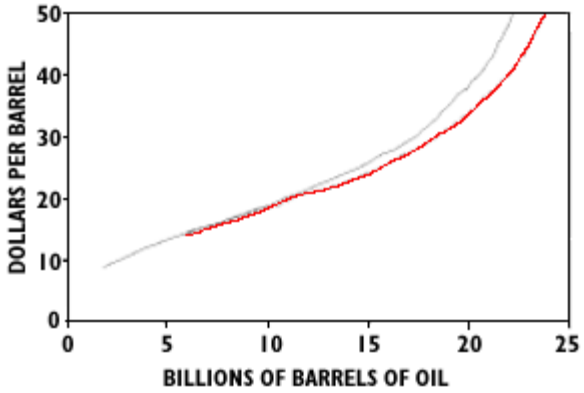

Figure 2. Incremental costs, in dollars per barrel, of finding, developing, and producing crude oil from undiscovered conventional oil fields and continuous-type oil accumulations in onshore and State offshore areas of the United States. Black line represents undiscovered conventional oil, and red line represents total of undiscovered conventional oil and oil in continuous-type accumulations.

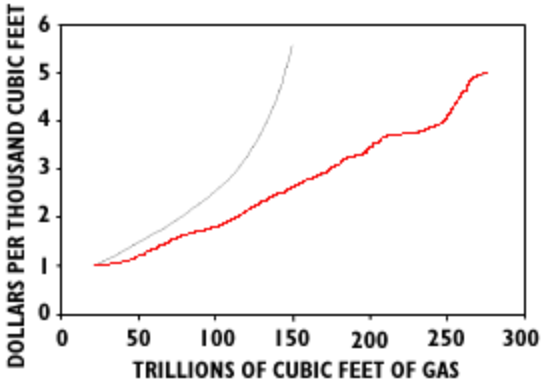

Figure 3. Incremental costs, in dollars per thousand cubic feet, of finding, developing, and producing undiscovered conventional total gas in oil and gas fields and unconventional total gas (that is, gas in continuous-type accumulations, including coal-bed gas) in onshore and State offshore areas of the United States. Black line represents undiscovered conventional gas, and red line represents total of undiscovered conventional and unconventional gas.

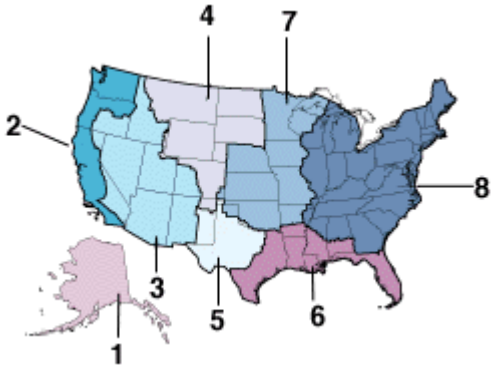

Figure 4. The eight regions of the United States as defined for the 1995 National Assessment of United States Oil and Gas Resources (U.S. Geological Survey, National Oil and Gas Resource Assessment Team, 1995). Region names and numbers are given in **table 1**.

More than half of the undiscovered conventional natural gas is concentrated in the Gulf Coast. Unconventional gas, particularly that available at higher prices, is concentrated in two locations -- the Colorado Plateau and Basin and Range Region and the Eastern Region -- both of which could serve major industrial markets. **Table 1** also shows the amount of natural gas available as associated gas (in oil fields) and additional hydrocarbon liquids from oil and gas fields in the form of natural gas liquids (NGL). Associated gas accounts for about 20 percent of total economically recoverable undiscovered conventional gas. NGL from both associated and non-associated gas accounts for 20-25 percent of total liquid hydrocarbons (crude oil plus NGL).

Table 1 contains no mention of field growth (inferred reserves). Estimates of undiscovered conventional and unconventional resources in the 1995 assessment already include allowances for field growth based on historical data. Field growth can occur through enhanced recovery methods that allow more resource to be extracted from known pools, through discovery of new oil pools in existing fields, through extensions of existing fields, and through reevaluation of

available reserves. To a significant degree, these factors depend on advances in technology and information, advances that are unpredictable. Although available historical data were insufficient to tie costs to volumes of hydrocarbon reserve additions associated with field growth, it appears that their incremental costs are, on average, lower than costs associated with new field development but higher than costs of producing proved reserves.

The Bottom Line

Figure 5 shows the amount of crude oil, a total of 68.7 billion barrels, that could be made available from various sources through 2015. Figure 6 provides the same type of information for natural gas in oil and gas accumulations, which totals 474 trillion cubic feet. These diagrams include (1) economic quantities of undiscovered conventional and unconventional oil and gas evaluated at $30 per barrel of oil and at $3.34 per mcf of gas; (2) proved reserves on record as of January 1994; and (3) projections of field growth (inferred reserves in the assessment) from 1994 through 2015 for pre-1992 discoveries. Field growth accounts for 44 percent of the projected reserves of oil and 30 percent of the total reserves of natural gas.

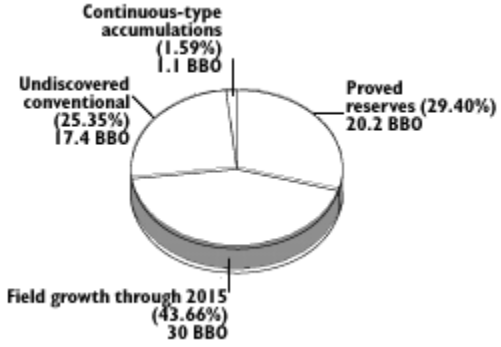

Figure 5. Estimated shares, as of January 1994, of crude oil that could be available for production during the next two decades through 2015. Sources consist of proved crude oil reserves, field growth through 2015 for fields discovered before 1992, estimates of economic crude oil in undiscovered conventional oil fields, and economic crude oil from continuous-type oil accumulations. Estimates of economic oil assumed incremental costs of $30 per barrel for oil and $3.34 per mcf for associated gas. Total crude oil represented is 68.7 billion barrels.

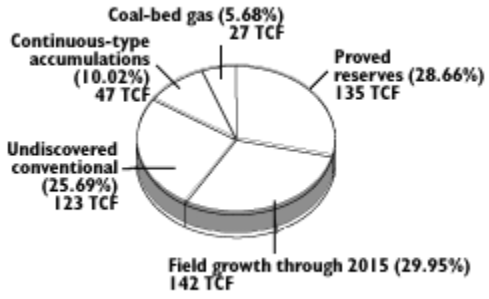

Figure 6. Estimated shares, as of January 1994, of total gas that could be available for production during the next two decades through 2015. Sources consist of proved total gas reserves, field growth through 2015 for fields discovered before 1992, estimates of economic gas in undiscovered conventional oil and gas fields, and economic gas in continuous-type oil and gas accumulations, including economic coal-bed gas. Estimates of economic gas assumed incremental costs of $3.34 per thousand cubic feet for gas and $30

BBO, billions of barrels of oil.	per barrel for oil. Total quantity of gas represented is 474 trillion cubic feet. TCF, trillion cubic feet.

The estimates reported in the USGS 1995 national assessment are based on geologic data and probability analysis and are reported as ranges with different levels of confidence. The single numbers from the assessment shown in **figure 1** are the mean volumes expected to be found but should not be considered in absolute terms - the actual volumes ultimately discovered will vary from these numbers. The most significant results of the assessment are those that have to do with exploration and production trends and location of undiscovered resources, not absolute volumes. Similarly, economic models are best at suggesting the general direction and magnitude of trends rather than making precise predictions. Perhaps the most important conclusion of the economic analysis is the observation that -- even with the projected amounts from inferred reserves and real price increases to $30 per barrel (or $3.34 per mcf) -- to sustain production at 1994 levels will require significant improvements in exploration and production technology.

A Comment on Economic Methodology

In contemplating the meaning of the economic analysis, or in using its results for further analytical or planning purposes, one must consider the time context of its methodology. The economic analysis is time independent. It predicts the price per barrel of oil or thousand feet of natural gas that it would currently take, with present technology, to convert undiscovered resources into proved reserves and to produce the reserves. Of course, it takes time to drill the wells necessary to prove the reserves, but during that time, both technology and scientific understanding will continue to evolve. Over the past two decades, for example, a number of geological and technological breakthroughs have been made that have led to significant efficiencies in exploration for, and development of, oil and gas resources. These include the following:

- Development and application of sequence stratigraphy to exploration analysis, a concept that allows scientists to predict with significantly greater accuracy the presence and location of source rocks, reservoir rocks, and stratigraphic traps.
- Digital reprocessing of existing seismic profiles, making it easier to identify geologic features.
- Three-dimensional seismic techniques that provide detailed images of the subsurface and the precise location of potential oil and gas traps.
- Directional drilling, which enables a driller to aim at highly specific underground targets as far as 5 miles from the drill site.

The North Slope of Alaska provides an excellent example of the effect that these advances have had on the relationship between oil price and volume of resource that is economically recoverable. During the 1970's and 80's, exploration effort focused on finding billion-barrel fields -- fields of less than several hundred million barrels were considered uneconomic at anything less than the inflated prices of the early 1980's. Only a few fields were discovered that fulfilled the apparent size requirements. However, today, accumulations as small as 50 million barrels are considered to be of economic interest. This change has created a dynamic revolution in North Slope oil exploration and production. This revolution is driven by economies stemming from the advances mentioned above and is bolstered by the existence of the transportation infrastructure associated with the Trans-Alaska Pipeline.

Similar advances in scientific understanding and technological expertise could take place during the time it would take to drill the wells necessary to turn present undiscovered resources into proved reserves. This possibility of advances suggests that estimates of undiscovered economic resources provided here are minimal. If significant scientific and (or) technological advances occur during the development of these resources, the volume of economically recoverable resources will increase under the same price assumptions. Alternatively, the estimated volumes might be produced at lower price points.

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