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Link between endowments, economics and environment in conventional and unconventional gas reservoirs

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HIGHLIGHTS

- Characterization of conventional, tight, shale and coalbed methane reservoirs.
- Variable Shape Distribution model used to estimate global gas quantities.
- Gas supply curves used to assess economic viability.
- Gas is abundant and costs of unconventional production is comparable to conventional.

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ABSTRACT

This paper presents a methodology for connecting endowments, economics and the environment in conventional, tight, shale and Coalbed Methane (CBM) reservoirs. The volumetric estimates are generated by a Variable Shape Distribution model (VSD). The VSD has been shown in the past to be useful for the evaluation of conventional and tight gas reservoirs. However, this is the first paper in which the method is used to also include shale gas and CBM formations. Results indicate a total gas endowment of 70,000 tcf, split between 15,000 tcf in conventional reservoirs, 15,000 tcf in tight gas, 30,000 tcf in shale gas and 10,000 tcf in CBM reservoirs. Thus, natural gas formations have potential to provide a significant contribution to global energy demand estimated at approximately 790 quads by 2035.

A common thread between unconventional formations is that nearly all of them must be hydraulically fractured to attain commercial production. A significant volume of data indicates that the probabilities of hydraulic fracturing (fracking) fluids and/or methane contaminating ground water through the hydraulically-created fractures are very low. Since fracking has also raised questions about the economic viability of producing unconventional gas in some parts of the world, supply curves are estimated in this paper for the global gas portfolio. The curves show that, in some cases, the costs of producing gas from unconventional reservoirs are comparable to those of conventional gas.

The conclusion is that there is enough natural gas to supply the energy market for nearly 400 years at current rates of consumption and 110 years with a growth rate in production of 2% per year. With appropriate regulation, this may be done safely, commercially, and in a manner that is more benign to the environment as compared with other fossil fuels.

1. Introduction

This study aims to present an overview of various aspects associated with unconventional natural gas. Apart from serving as an extensive literature review, the paper also presents original estimates of unconventional gas quantities and production costs. We argue that the topics of focus are highly interconnected. For instance, Fig. 1 is a pentagon showing the link between rocks (geology), hydraulic fracturing, economics, environment, and the global gas portfolio. Our view is that there must be equilibrium in the pentagon to provide a win–win situation for society at large. All corners in the pentagon are interrelated and there is no need to sacrifice one for benefit another. It has been shown that there is a significant gas endowment in conventional reservoirs. However, we have to also unlock natural gas stored in unconventional

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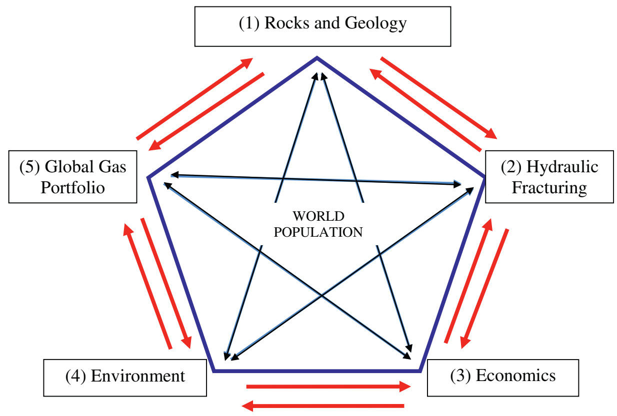

Fig. 1. Link between rocks, hydraulic fracturing, economics, environment, and the global gas portfolio. There has to be equilibrium between the 5 corners of the pentagon to provide a win–win situation for society at large.

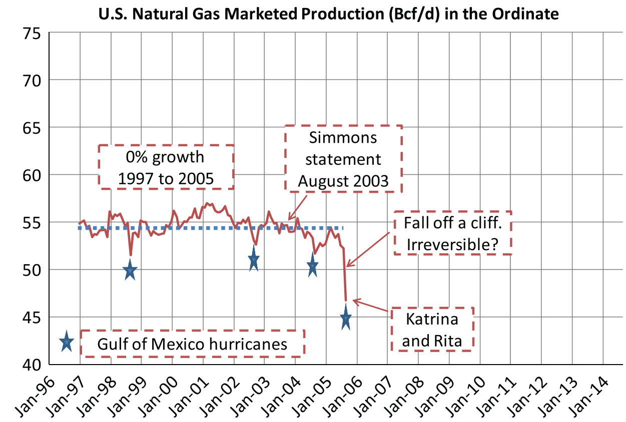

Fig. 2A. Pre-2006 actual natural gas marketed production in the United States (data from EIA).

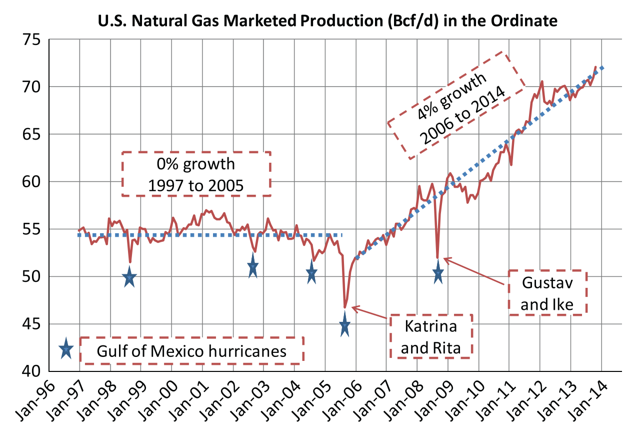

Fig. 2B. Post-2006 actual natural gas marketed production in the United States shows a mirror image of the 2003 forecast with a significant increase in production (data from EIA).

formations to ensure that gas plays an important role in satisfying future energy consumption. We cannot produce it economically without hydraulically fracturing the unconventional formations. At the same time, we cannot sacrifice the environment solely for economic gain and nothing but the highest environmental standards are acceptable. All stakeholders must act responsibly to generate the win–win scenarios.

The natural gas industry is at present a victim of its own success. A gas bubble has resulted in a drop in prices during the last few years in North America, which has made the economics unattractive for oil and gas companies. The gas bubble is the result of innovation, but innovation is nothing new in the oil and gas industry. For example, the Bureau of Economic Geology at the University of Texas (Austin) presented an evaluation of Federal, State and private investment in unconventional natural gas research in the US [1]. The study indicated that "the supply curves benefited greatly from natural gas research and the successful application of technology." Although the R&D investment was relatively modest, the tight gas production curve did show a large positive increase in slope in 1985 following $165 million of combined investment in research by the Department of Energy (DOE) and the Gas Research Institute (GRI). "Studies were focused on advanced stimulation technology, the greater Green River Basin, and the Piceance Basin." Subsequently, shale gas came of age in the United States with innovation in the drilling of horizontal wells and development of technology for multi-stage hydraulic fracturing; while hydraulic fracturing has been in practice commercially since 1949, the multi-stage advances have been critical in lowering costs. Although the results have been outstanding, the forecasts by 2003 were dire as some experts indicated there was going to be "irreversible decline" in natural gas production in North America and that gas production rates would "fall off a cliff." For example, the following statement by Mathew Simmons (2003) created some concern: "people need to understand the concept of peaking and irreversible decline. It's a sharper issue with gas, which does not follow a bell curve but tends to fall off a cliff. Pray for no hurricanes and to stop the erosion of natural gas supplies. Under the best of circumstances, if all prayers are answered there will be no crisis for maybe two years. After that it's a certainty." [2] These forecasts got some attention when production fell dramatically in the US as a result of hurricanes Katrina and Rita (Fig. 2A). However, actual gas production became a mirror image of the "fall off a cliff" prediction (Fig. 2B). The success, highly dependent on multi-stage hydraulic fracturing, has resulted in accusations that this type of stimulation leads to environmental problems – particularly related to contamination of ground water by methane and chemicals used in the fracturing jobs. However, the possibilities of this happening through hydraulic fractures created during stimulation jobs are very slim. To reduce the probabilities of environmental problems, special care has to be taken during the wellbore construction and casing cementation. As society will require increasing energy in the future, the use of natural gas should be encouraged as this is the cleanest fossil fuel available (as summarized in the environmental segment of Table 1).

The development of effective technology for tight and shale gas formations can be explained using Foster's S-shape curve (1986) adapted to the case of unconventional gas in the United States, Canada and the world [3]. Fig. 3A shows our interpretation of innovation associated with unconventional natural gas in the United States. The very small amount of research funding indicated above provided a seed for initially slow but encouraging advancement. This corresponds to the end of the S curve at the bottom left hand corner. This led to many additional investments by the oil industry in the United States on tight gas sandstones and subsequently shale gas (and liquids), thus moving through the steep part of the S curve. Foster has indicated that "youthful attackers" have generally provided the possibility of new technological development and innovation. The same holds true in the oil and gas industry where smaller companies took the lead on development of unconventional resources. The steep part of the S-curve is where, to paraphrase Foster, all hell broke loose as "the key knowledge necessary to make advances" was put in place. The flat part at