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The Resource Hierarchy Relationship

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Abstract

Estimates of technically recoverable resource (TRR) are a necessary part of any long-term projection of future hydrocarbon production. TRR can be related to economically recoverable resources (ERR) and original resource in-place (ORIP) by the following relation: 0 <= ERR <= TRR <= ORIP. It is therefore possible to indirectly bound TRR within the context of ERR and in-place estimates, as opposed to estimating it directly.

Estimates of TRR have an implicit or explicit relationship to price, and the accompanying application of technology or industry practice allowed by that price. TRR can be estimated without solving for the upper constraint of total resource size, but a more thorough understanding of the total resource equation is obtained by including the geologically based upper limit.

Introduction

The U.S. Energy Information Administration (EIA) produces projections of oil and natural gas production over time periods up to 25 years in the future using the National Energy Modeling System (NEMS). Critical to these projections is the estimate of the rates at which TRR volumes are converted into economic production. Better understanding the magnitude of TRR or the way TRR volumes are converted into ERR and thereafter into production is critical to improve the NEMS model in this area.

Discussion of the relationship

ORIP, TRR, and ERR are three complimentary measures of the size of a given hydrocarbon resource, where the resource is defined volumetrically by its geographic extent, geologic origins, and storage characteristics. The amount of ORIP is typically estimated based upon its geologic characteristics, and it is independent of fact or nature of that resource's recovery. Specifically, ORIP does not depend upon the technologies used in exploration or production, any particular industry practices, or an assumed commodity price. TRR represents the volumes of the ORIP that could be recovered using certain assumptions about technology and industry practices, irrespective of costs or resource prices. Since the full volumes of a resource are rarely recovered, TRR can be represented as a fraction (often called the recovery factor) of ORIP. ERR is that volume within the estimate of TRR that could be recovered economically under the same technology and industry practice assumptions used to estimate TRR but under specified economic conditions (typically fixed per-well costs and commodity prices). The hierarchical nature of these three resource estimates can be expressed mathematically with the following inequality:

$$0 \leq ERR \leq TRR \leq ORIP$$

The lower bound is axiomatic, since a given resource may be completely uneconomic to develop at the given price. The upper constraint (ORIP) may be uncertain to several orders of magnitude, based upon the level of understanding and data available for a given resource, as well as the estimation methodology. No considerations of development technology, technological change, common practice, or price are necessary to create this estimate, as it relies entirely on geologic information. Therefore, although the ORIP itself does not change over non-geologic time scales, estimates of ORIP can improve as more data is collected and more knowledge is gained about a resource.

Estimates of ERR and TRR are not only geologic in nature. They are also dependent upon assumptions of development technology, technological change, industry best- or common-practice, and costs and prices. These assumptions must be included (implicitly or explicitly) in any estimate of ERR or TRR, and they can change over time as prices and industry practices evolve. Notably, although TRR is not a direct function of commodity prices or drilling costs, the economics of resource extraction, including both commodity prices and technology change, can influence industry practices over time. If TRR estimates are based on current industry practices, then economics and technology change can indirectly influence expectations for TRR.

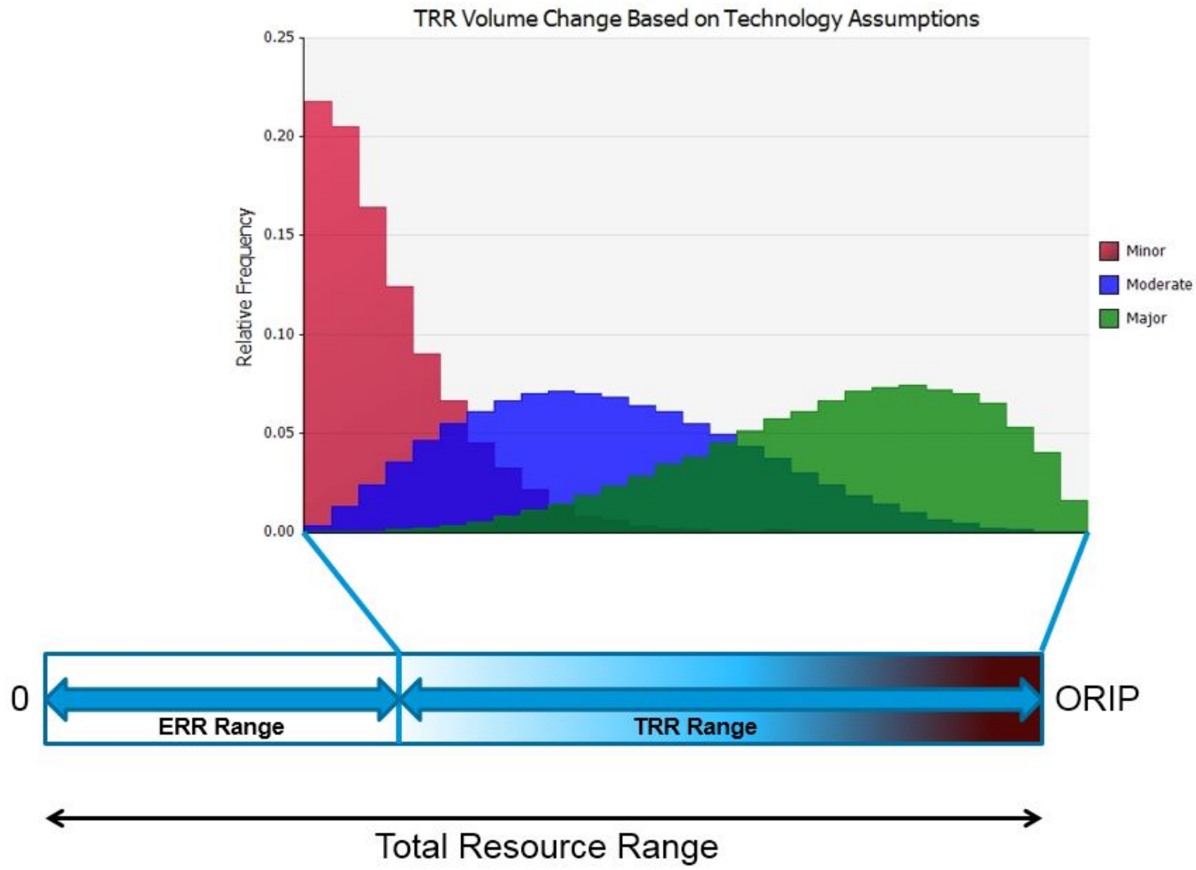
The mathematical relationships between ORIP, TRR, and ERR may be used to constrain the values of TRR, using common assumptions about 1) geology, 2) technology and engineering practices, and 3) economics. There are many ways to estimate ERR, but typically it is estimated by simulating the development of a given resource over time either econometrically, by assuming an archetypal development profile, or through some sort of economic simulation model. If modeled correctly using the same geologic assumptions, an estimate of ERR will be less than an estimate of the same resource's ORIP, and the difference between ERR and ORIP is the full range of all potential estimates of TRR, given a set of industry practices and available technologies.

TRR is often thought of as the maximum potential resource recovery volume possible from a given resource. However, since TRR is constrained on the down side by ERR, it could increase over time as ERR increases. For example, if commodity prices increase enabling the economic application of new technologies and/or industry practices, the application of these new techniques across an entire resource would be expected to change estimates of both ERR and TRR in the same direction so that ERR retains its mathematical relationship with TRR. Similarly, both TRR and ERR would be expected to change accordingly as ORIP estimates are refined.

There are substantial implications for TRR estimates from this: 1) The full range of potential TRR can be calculated indirectly based on two other estimates. It could also be calculated starting from the assumptions of either bound. A TRR estimate could be built upwards from ERR by extending current technologies and industry practices to undeveloped areas within a play, or downwards from ORIP by assuming drawing board technologies that are not yet cost competitive. 2) There is no requirement to express a TRR estimate as a point estimate between two extremes. The uncertainty involved within a geologically based ORIP estimate lends itself to creating stochastically based estimates of TRR, as do the results of conditions, practice, or circumstances of new or yet to-be-discovered technologies. 3) TRR estimates are generally snapshots in time, specific to the conditions that apply at the moment they are generated. It is therefore possible that static estimates of TRR can be outdated nearly as fast as they are created, if they do not account for the progression of time and the technological changes that come with it. Past changes in TRR, and the reasons for those changes, can be projected into the future. By extension, one could assume that adjustments to today's estimates of TRR, as time and technology progress, would be required when projecting resource development more than a few years into the future. It cannot be assumed that the effects of changes in technology cease the day the any estimate of TRR is made.

Graphical expression of the relationship

Figure 1 is a notional graphical representation of the resource hierarchy equation, and the three implications from the preceding paragraph.



Source: U.S. Energy Administration, Office of Energy Analysis, Petroleum, Natural Gas and Biofuels Analysis

Figure 1. *Economically recoverable resource range and technically recoverable resource range represent an uncertain amount of resource within these categories, bounded by 0 and ORIP. The increasingly darker shading within the TRR Range signifies increasingly difficult and /or expensive extraction as the original resource in place limit is approached. The technically recoverable resource range might be further described by multiple probability density functions demonstrated as Minor, Moderate and Major improvements over current technology or industry practice.*

The red probability density function in figure 1 represents a TRR estimate that most closely resembles the ERR estimate, and is assumed to include only minor revisions or improvements to current technology or industry best practice. The blue probability density function in figure 1 could be used to represent a moderate application of an experimental technology that might not be economic today, or even practical, but that can be expected to make an impact in the future on an estimate of TRR. The green probability density function in figure 1 could best be described as a recovery of resource more closely resembling mining. The transition of TRR estimate in figure 1 from red through blue to green is analogous to the changes in the past as improved technologies have unlocked old resources that were once considered uneconomic or unattainable with the technology, practice or price of that day.

It should be pointed out that nothing within the resource hierarchy relation precludes increases or decreases in TRR estimates or range. It is possible that upon reevaluation, the ORIP estimate is far smaller than initially estimated, and when the upper constraint becomes lower, all other estimates will follow. It logically follows that if ORIP is known to an absolute certainty, as ERR gradually increases with time and extraction, the range of TRR potential will shrink, and conceivably disappear altogether as the full amount of resource can be developed economically.

Practical application of the relationship

There are many methods of estimating technically recoverable resources, widely variable in scale across area and volumes, from singular or multiple geologic units, and varying degrees of resource concentrations. Examples of these ranges are discrete oil and gas reservoirs within a total petroleum system containing multiple source or reservoir rocks in an entire basin, or sweet spots in single formations in continuous accumulations subdivided into much smaller areas.

The resource hierarchy relationship holds within any given context, but it should be noted that the practical application will be more useful at the smaller scales. This derives from a lessening in value of the upper resource in place constraint as it approaches the equivalent of crustal abundance for a given geologic entity being assessed. In contrast, the relationship provides more insight when applied to discrete reservoirs and discovered oil and gas fields or focused on tight/shale productive intervals within play level accumulations such as Susquehanna County Pennsylvania within the Marcellus formation. Under these conditions it can be used to full advantage to test changes in TRR estimates as underlying changes in price, technology or geologic knowledge or assumptions change. A future EIA working paper will provide a small scale example to determine how TRR might change with increases in drilled well densities in the Bakken formation of North Dakota.

Conclusions

The resource hierarchy relationship provides the context that resource categories operate within. TRR is the category that operates as a measure of future inventory, volumes available with the right application of technology, itself dependent upon an expectation of future prices that would make a given technology available. To access those volumes, they must first transition into the realm of the economically recoverable, at which point they become available to convert into production.

Within the resource hierarchy relation, estimates of TRR are bounded by, depend upon, and can be changed by estimates of, or change in assumptions of, the economically based ERR estimates and the geologically based ORIP estimates. Estimates of TRR are therefore not static in nature, and snapshots of TRR will require modification or adjustments over time as economic, technological and geologic assumptions and understanding change. These expected changes in TRR must be accounted for in any long term resource production model.