Have we underestimated the environmental challenge?

The oil and gas industry annually reports global proven reserves, which investment, energy and environmental analysts incorporate into future strategies. But in planning for the forthcoming decades, a major error has been made, claims Richard Pike, *Chief Executive, Royal Society of Chemistry.*

The increasingly intense debate on energy and environmental issues brings to light a fundamental misconception over the magnitude of global proven reserves of oil and gas. Merely adding arithmetically the proven reserves reported by each of the oil-rich countries of the world significantly underestimates the true figure for this global reserves category.

These, together with their reservoir and field source data, instead need to be added probabilistically rather than arithmetically, with the result that the true proven reserves for the world (preserving the same 90% confidence level) may be nearly twice the conventional figure, with the most likely reserves (proved plus probable) being still greater. This reflects the statistical characteristics of the 'bell-shaped' reserves size distribution found within typical reservoirs.

Discovered but uncommercial hydrocarbons (contingent resources), together with as-yet undiscovered resources could make the total even greater. We should not be surprised if, potentially, hydrocarbons could dominate well into the 22nd century.

While this calls into question the global applicability of individual proven reserves figures currently submitted by companies and countries, it particularly highlights a major error in future energy and environmental planning. As will be seen in what follows, numbers derived for one purpose are being used erroneously for another. We are dramatically under-estimating the environmental challenge facing us, and the demands that will be placed on the capture and sequestration of carbon dioxide (CO_2) in the future.

Problems of aggregation

According to definitions used in the industry, the proven reserves of an individual reservoir represent that discovered, recoverable and commercially available volume (P90) that has a 90% probability of being exceeded. When aggregating the data from individual reservoirs to the field level, many companies merely add arithmetically, although some apply a probabilistic approach.

Consolidating to the company level is almost always arithmetical, and this is considered acceptable by the financial markets because its principal purpose is to provide a conservative estimate for reserves that gives investors a high degree of confidence of being recovered. This form of aggregation continues to the country and world level. This is equivalent to assuming that the outcome simultaneously of every field in the world will be its downside, with no scope for upside beyond the P90 threshold.

With the compartmentalisation of the oil and gas industry, most investment, energy and environmental analysts dealing at the strategic, global level seem unaware that the public reporting of proven reserves alone – and the way they are added up – is purely a historic convention. It bears little relevance to what will be actually produced. Such analysts are constrained, however, by proven reserves being the only indicator widely available in the public domain.

In practice, companies developing their fields place far more emphasis on the proven plus probable reserves (P50), as this determines what hydrocarbons are produced, the number of wells drilled, and the extent of surface facilities constructed. The expected future production profiles of those fields already onstream are usually filed with the government of the country in question, but are seldom readily available to the public.

Consequences

The overall consequences of the present calculation and use of proven reserves are summarised in the accompanying schematics explaining the background to the probabilistic approach described above. **Figure 1** clarifies currently used definitions, while **Figure 2** illustrates the outcome in adding probabilistically two

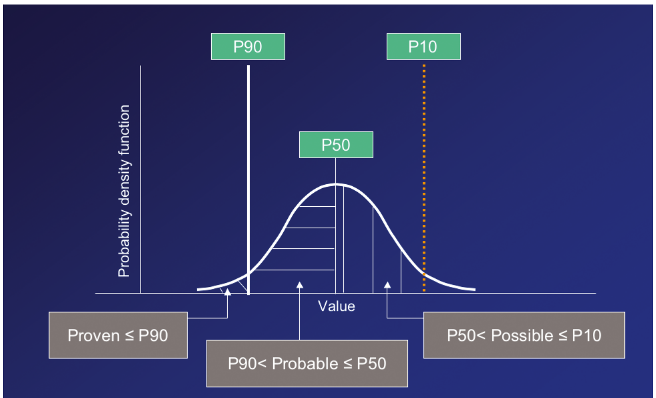

Figure 1: Comparability of reserves terms

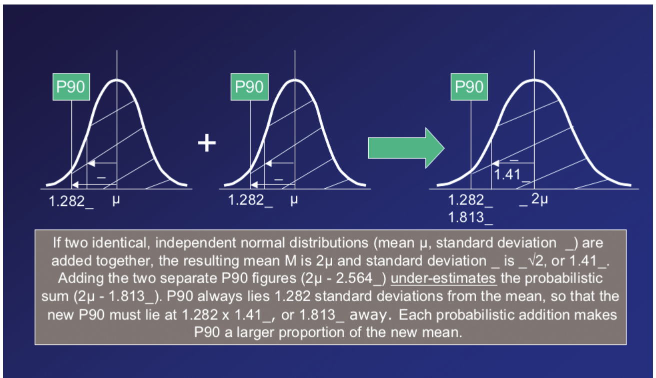

Figure 2: Probability applied to the addition of STOOIP (stock tank oil originally in place) or reserves

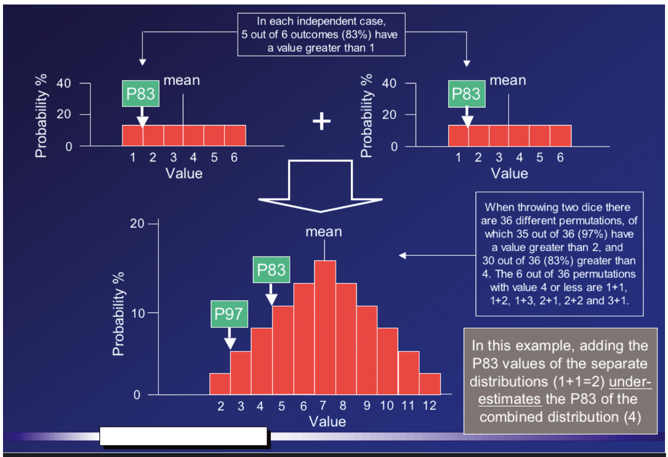

Figure 3: Lessons from two dice

identical normal distributions, which broadly represent the characteristics of reservoirs. Typically, P50 is two or three times P90 for a reservoir in the early stages of production, although this ratio reduces as more information is gathered for producing assets.

Under these circumstances, the square of the standard deviation of the combined distribution is equal to the sum of the squares of the separate distributions. The effect of aggregation is to 'squeeze' the standard deviation relative to the mean with the addition of each new distribution. P90 always lies 1.282 standard deviations away from the mean, and this becomes a higher proportion of P50 as the aggregations continue. Merely adding the individual P90 figures arithmetically underestimates progressively the true P90 of the combined distributions. What is actually being derived is the P99.99……. at the global scale.

Numerical implications

The quantitative implications of the confusion over definitions and aggregation of probabilities are significant. Peter Odell, in his book published in 2004 entitled *Why carbon fuels will dominate the 21st century's global energy economy*, summarises the views of others that the initial global oil resources were approximately 3,000bn barrels – an estimate that has remained largely unchanged for the last 10 to 15 years.

In details on oil given to support this figure in 1995, around 788bn barrels was estimated to have been produced up to that time, a further 1,095bn barrels were deemed proven reserves, 750bn barrels were yet to be discovered, and the implied difference (367bn barrels) attributable to current and new technologies applied to known fields. This excludes unconventional oil resources, such as tar sands.

The true P90 of the reserves category will have been significantly more than the 1,095bn barrels indicated (and the 1,189bn barrels reported elsewhere for end-2004) for the reasons presented here, but this and the crucial, higher P50 cannot be quantified because of the limited data in the public domain. Similar observations can be made for the reporting of gas resources. There is the prospect, therefore, that hydrocarbons will dominate even beyond Odell's projections. This also raises the question of the relevance, to global energy and environmental management, of the ratio of proven reserves to current world production (40 years for oil) as presently calculated, when likely recoverable resources are so much greater.

Lessons from two dice

Intuitively, we would expect that arithmetical adding is incorrect. Our everyday experience of lower-bounds is that they do not all occur simultaneously. Some events yield an upside while others give a downside.

Figure 3 illustrates the lessons to be learned from playing with two dice. Throw a single die, and the probability of the outcome exceeding 1 is five out of six, or 83%. Using the above terminology, the P83 figure is 1. Throw two dice together, and the P83 figure is 4, or twice the simple arithmetic aggregation of the two separate distributions. This is because 30 out of 36 permutations give a sum greater than 4. This really is a case of 1 + 1 = 4, instead of 2.

Remedies

Rather than there being general agreement on the quantitative limits of these resources, which would encourage all parties to address remedies and also seek out alternative energy routes, the relative abundance of oil recognised by individual producers themselves may inhibit this search.

Despite transparency and innovative approaches by some of the leading oil companies, the overall global response has been inconsistent and uncoordinated. In practice, those countries dependent on petroleum for national revenues will be under domestic pressure to continue to develop their significant assets.

There is also anecdotal evidence that some countries are under-reporting proven reserves to maintain a high oil price. Altogether, as a result, the world is under-stating the environmental challenge facing generations to come, and appears unprepared for the difficult compromises that will have to be made.

For more coherent global energy and environmental planning, it will be essential to use estimates that reflect proven plus probable reserves, and address issues of openness and confidentiality that this raises.

We are faced with numerous decisions in the near future, which lie on a spectrum of increasing difficulty. They are likely to include selective curtailment of coal, oil and gas production, sequestration of CO_2, expansion of alternative energy sources (including biofuels, wind, tidal and solar, and hydrogen derived through various routes), revitalising the nuclear industry, chemical removal of CO_2 from the atmosphere (including artificial photosynthesis) and reforestation.

It will also require economic, technical and infrastructural support to emerging countries that would otherwise rely on their own hydrocarbon industries. In what seems like an echo from the nuclear industry, for any CO_2 'stored' physically or chemically, it will be crucial to minimise the risk of releases into the atmosphere in the centuries to come.

Solutions will need to cross technical, social and geo-political boundaries, and rarely can there have been a greater need for a broad understanding of such complex issues, their possible solutions and consequences. Informed and fact-based views will be essential for getting the right balance.

Education and training

The public and industry confusion over just how much oil and gas there is suggests the need for more focus on the quantification of environmental issues. This must start with setting much higher expectations on what education and training deliver in terms of science and mathematics skills, and the ability to challenge effectively the status quo, including traditional conventions found in the oil and gas industry.

We could then all be more assured that the solutions being proposed were the right ones, and that they could be implemented successfully. ●