An In-Depth View of Future World Oil & Gas Supply:

A Quantitative Model Analysis

By Rafael Sandrea, PhD

An Oil & Gas Journal Research Center™
Multiclient Study From PennEnergy™

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Executive Summary

Chapter 1

This chapter gives a quick look at the development of the oil and gas industry from its inception to its absolute importance in today's world. The evolution of supply, demand, prices, and resources discovered since the 1900s are highlighted and finally connected to the goals of this report which are numerous:

- development of a physical model to predict the real production capacity of oil and gas reserves over the medium and long term. This model provides a real time comparison of accessible supply with the projected global demand outlooks of reputable institutions, and quantifies the future crude oil and natural gas production capacity of the Big Three producers – the US, Russia, and Saudi Arabia, through the end of the century.
- appraisal of oil and gas reserves, and in-place volumes (resources) discovered so far, globally and for the top producing countries. This is fundamental since reserves are the foundation for determining the production capacity of oil and gas fields. Oil resources are further broken down by their depth and API gravity – light, medium, heavy and extra-heavy – important indicators of their aptness for recovery by the variety of EOR technologies.
- assessment of offshore reserves and production potential. Offshore has been the main source of growth for world oil and gas production during the last 2 decades and is critical for the supply equation.
- analysis of the development of unconventionals – shale oil, coalbed methane, shale gas, and tight sands gas – particularly in the US where major strides have been made over the last 2 decades. The object is to quantify their impact on supply in the medium term.
- development of special algorithms to provide an early estimate of the production capacity of new undeveloped oil and gas fields, an issue of vital importance to supply analysts and for the design of production facilities. Establishing the real potential of an oil or gas field may take several years after discovery, following a costly appraisal drilling program. These algorithms are also useful to estimate the ultimate reserves of oil and gas fields that have already peaked.
- The relationship between production decline and reserves depletion is mathematically defined. This facilitates a better understanding of the decline behavior of aggregates of oil and gas fields as occurs at the country and global levels.

Chapter 2

Estimates are given for the world's oil resource base, including extra-heavy oils from the Canadian and Orinoco oil sands. Light oils, which are the backbone of the industry, account for two-thirds of all global oil resources. Only a small fraction of the traditional (excluding extra-heavy oils) oil resource base has been produced so far. Estimates are given for the global natural gas resource base. Less that one-fifth has been produced. Estimates are also made of the oil and gas resource base of the ten top producing countries. The Big Three producers – Russia, Saudi Arabia and the U.S – together hold almost one-fourth of the global traditional oil and gas resources.

Chapter 3

The world is known to have substantial unconventional oil and natural gas resources that were largely overlooked until the last 20 years or so. The unconventionals reviewed are shale oil, tight sands gas, coalbed methane and shale gas. The object is to ascertain their medium-term supply potential.

Estimates are given for commercially viable oil shale deposits. Oil shales have yet to be proven economically recoverable on a large scale, and as such still remain a contingent resource without any measurable effect on oil supply in the medium term. The huge unconventional Bakken oil formation which has recently stirred much interest is reviewed.

The situation is very different for natural gas unconventionals – tight sands gas, coalbed methane and shale gas. The U.S has made significant strides in this area. Modest production from these three gas sources began in the 1980s and, thanks to major technological efforts, has grown to almost half of the present U.S. total natural gas output. Estimates are given for tight sands gas which currently accounts for one-third of the US ultimate gas reserves. Tight gas sands are located primarily in the Rocky Mountain region. Although they occur in many countries they have essentially remained unexploited outside the US, except in the case of a few fields that are associated with conventional gas resources.

Worldwide contingent resources of coalbed methane are estimated. Today, coalbed methane is a full fledged industry in its own right contributing ten percent of the US total gas production. Coalbed methane deposits are primarily located in the Rocky Mountain region. Development is now widespread around the globe with pilot projects in China, Australia and Russia.

Globally, shale gas activity is very low, with approximately two-thirds of this unconventional gas resource located in the US. In fact, the US is the only country with a large scale shale gas industry. Shale gas was the last of the three natural gas unconventionals to take-off, as late as the 1990s. At this time gas shales have low recovery factors. The challenge is to release the gas locked in these stubborn, almost impermeable rocks. Estimates are provided for the potential ultimate recoverable resources of shale gas distributed throughout the US, offering attractive development costs.

The reservoir basics of tight gas sands, coalbed methane and gas shales are also discussed in this chapter.

Chapter 4

The types of reserves are defined, and a comprehensive overview of the evolution of their classification systems and of the methodologies for reserves estimation is presented. The US Securities and Exchange Commission's (SEC) system of reserves valuation is sketched out, indicating that it has had a notable effect on the quality of reserves disclosures for new oil and gas projects worldwide. The SEC's recently (December, 2008) approved revised reporting rulings are also outlined, together with observations by some major investors regarding risk profile assessments associated with carbon-related and climate regulations.

Decline analysis is used to determine the ultimate reserves of several giant oil and gas fields, and of the top ten oil and gas producing countries. The dilemma of extreme values of "reported" country-level reserves is examined; these values warp the usefulness of oil statistics in detriment of the general public and even for planning by national governments.

The ultimate reserves of traditional oil at the global level are established, and their half-life assessed. Half-life marks the beginning of production decline. The ultimate oil reserves and half-lives of the top 10 producers are established.

Contrary to the case of mature oil reserves, global natural gas is on a strong growth path having produced barely one-fifth of its ultimate reserves. This precludes decline analysis, so a heuristic approach based on an assumed analogy of the size distributions of giant oil and gas fields was used to assess its reserves. The value is obtained for ultimate recoverable gas resources, globally and for the US.

Chapter 5

Light oils are the cream of the crop and comprise two-thirds of the world's traditional oil resources – and only a small fraction has been produced so far. The overall expected recovery efficiency estimate is provided. EOR is indispensable to extract this massive volume of oil left in the underground while extending the economic life of the abundant mature oil fields. However, at the present time, only a tiny fraction of the world's oil production comes from EOR.

Opportunely, EOR is now very competitive thanks to the new levels of oil prices. What is at stake is that each percentage point increase in the recovery factor would unlock vast amounts of oil reserves from known reservoirs, thus reducing the need to rely so heavily on new discoveries. Estimates for both are provided and compared.

How fast can EOR be implemented on a large scale depends on the availability of high levels of investment, engineering manpower and many more technical considerations. This chapter outlines a realistic plan for implementing EOR worldwide and provides projected incremental production levels over a medium-term timeframe. Thereafter, with more experience, the rate of incorporating new EOR oil most likely would quicken.

In order to facilitate a general assessment of the applicability of the variety of EOR techniques available, the global oil resource base was sorted by reservoir depth – deep, intermediate and shallow – and by API gravity – light, medium, heavy and extra-heavy crude – categories that reflect as best as possible the upper and lower limits of successful field EOR projects. A long term tenable recovery goal is also provided.

Chapter 6

Global offshore oil production is critical for the supply equation. In fact, it has been the main source of growth for world oil production in recent years, as onshore output has been essentially flat during the last two decades. The performance of the global offshore production sector has been remarkable. The emerging ultra deepwater play is discussed, and in particular the recent large subsalt finds off Brazil.

Offshore oil and gas production together account for almost one-third of the oil-equivalent world production. A scenario for medium-term offshore oil production is provided.

Chapter 7

Our knowledge of the existing hydrocarbon resource base is now at a 90 percent confidence level, which provides a fairly solid platform from which to build a profile of oil and gas production in the 21st century. A physical decline model is physical model developed to predict the future production capacity of the crude oil and natural gas reserves, worldwide and for important oil producing countries. Crude oil accounts for four-fifths of the world's present petroleum liquids supply mix of 85 million b/d. It should be emphasized that the projections of crude oil and natural gas production correspond to the maximum production capacity that their reserves can sustain at any time. In other words, it represents the best case output scenario of crude oil and natural gas.

The decline model differs substantially from other models. Some use a "bottom-up" methodology based on building individual profiles of key oil fields – in effect a sample-like analysis valid at best for medium term supply predictions. Others, like the EIA model, essentially assume an unlimited growth of reserves and consequently of production. The decline model in effect constrains production growth to the capacity of the known proved reserves; its parameters are obtained by previously fitting the model to the entire production history of all producing fields. In this report, medium-term projections from the decline model are compared with those of the EIA model for oil and natural gas. Potential shortfalls of global oil production capacity in the absence of a comprehensive EOR effort are projected.

In addition to global oil and gas projections, the report also presents long term projections of the crude production capacity of the US, Russia and Saudi Arabia, and natural gas projections for the U.S. In synthesis, the decline model provides a comprehensive global outlook of the medium and long term production potential of both crude oil and natural gas.