

C o m p r e h e n s i v e A s s e s s m e n t
o f

World Crude Oil Supply Through 2030

b y R a f a e l S a n d r e a , P h D
M a r c h , 2 0 1 2

*The Top 200 Producing Oil Fields, Reserves Appraisals,
and Outlooks for 31 Countries by Oil-Quality*

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Executive Summary

A comprehensive study has been conducted to provide an in-depth look at crude oil supply over the next 20 years. Past outlooks have been limited to a macroscopic view of global supply but now that we are on a critical pathway of imbalance between supply and demand it becomes necessary to look in more detail at supply starting at the producing country level. This study pursues this approach and dissects future supply capacity down to the oil-quality level for the 31 producing countries that account for 93% of total crude output, and their 200 top producing oil fields. We specifically concentrate on crude oil since it is the main source (85%) of the mix of petroleum liquids supply which includes NGLs (11%), biofuels (2%), and other liquids. More importantly, however, crude is the core of the oil market, from well-head to pipelines to tankers to refineries, and finally to the consumer. It is also the only source for on the spot adjustments to market disruptions if they should arise.

Chapter 1

The world has been producing crude oil for the last 150 years. Today, 90 countries produce a total of 74 million b/d, a level that has been essentially flat for the last 5 years in spite of the run-up in oil prices from \$27 in 2003 to an all time high of \$145 in mid July of 2008. Global petroleum liquids ('oil') supply, of which crude oil is the mainstay accounting for 85% of the total mix, hit an all time high of 87 million b/d in 2010 and forecasts (ExxonMobil, BP, Total, OPEC, EIA, and IEA among others) indicate that it should increase about 20 %, to 100-105 million b/d, by 2030. NGLs and biofuels have been the only sources of growth in oil supply since 2004 and this situation is expected to continue in the foreseeable future.

All crude oil produced goes to refineries – its primary destination – to be processed into diverse products within regional patterns of consumption and demand growth. Worldwide, the average quality of crude oil produce has been falling over the past three decades and refiners have to invest millions in their plants to refine the changing flow of crude. Production of light-sweet crudes, which are low in sulfur and cheaper to refine – the cream of the crop as they are referred to – is increasing slightly from a few places, especially West Africa. But that gain is more than offset by declining production of similar quality crudes from the North Sea and North Africa. Additionally, production of these high quality crudes has been affected recently with the civil war in Libya.

On the other hand, over the eons since oil became commercial we have discovered 11 trillion barrels of traditional oil resources (additionally there are 3 trillion barrels of extra heavy crude from the Canadian and Venezuelan oil sands) and have produced just 10% so far. Under current operational systems, we will recover at most another 12% or so, leaving behind 9 trillion barrels in the ground. Enhanced Oil Recovery (EOR) techniques, such as thermal, miscible and chemical processes, can double our reserves and provide us with supply for 80 years at current production rates! There is an old adage: 'the best place to find oil is in an oil field'. EOR production today accounts for only 3% of world crude oil production. EOR techniques and their success are closely related to the grade of crude oil.

The reality of a plateau in crude oil production capacity over the last six years which typically precedes the onset of production decline, leaves no doubt the importance, for producers and refiners, to have a clear vision not only of the global outlook of crude oil but of its grade distribution, and preferably at the producing country level. These are the core issues addressed in this study. The oil quality subject is equally important to traders and analysts.

This report presents production forecasts by oil grade distribution through 2025 for the 31 top oil producing countries that account for 93% of global crude oil output; for the seven producing regions; and gives three

outlook scenarios for global supply through 2030. Additionally, to set the stage for the report and offer a succinct full vision of the upstream industry, this chapter provides a quick-look ensemble of unique data for the top 44 oil producing countries and the seven producing regions: *latest production, consumption, export capacity, refining capacity and oil quality (API gravity and sulfur content), all within a single Table.*

Chapter 2

This chapter discusses the theme of oil quality and defines the crude oil classification system – API gravity and sulfur content – used in this study. The system is particularly important for both refiners and producers since it ultimately determines the commercial value of crude. Oil grade is also a fundamental parameter in oil field operations. It distinguishes the applicability of types of EOR techniques and, more importantly, their success. Benchmarking is briefly discussed because of its importance in trading, and the major producing regions of sweet and sour crudes are listed.

A distinctive compendium is presented of the top producing oil fields in each of the 31 top producing countries, detailing their *vintage, outputs, and crude quality*. This field data is then used to establish the average quality of the crude produced at the country and regional levels, and subsequently in the oil-grade segregation of our country outlooks in the final chapter. The field data brings to light two observations: a) relatively few of the 40,000+ oil fields around the world account for almost two-thirds of global output, and b) three-quarters of these top fields are mature – close to or past their mid-life – and are on the decline.

Chapter 3

In this chapter an extensive re-assessment is carried out of the developed reserves (EURs) in 31 countries which provide 93% of the total crude oil produced worldwide, and in the seven oil producing regions around the world. The basics of reserves evaluation are discussed and in particular the methodology of decline analysis which has been the bread-and-butter of the industry for the last 100 years! For contrast effects, ‘match stick’ decline rate trend lines are illustrated for the four oil regions in decline and for selected producing countries including the Big Three oil producers: Russia, Saudi Arabia, and the US, all of which are all past the mid-life of their reserves. Two-thirds of the 31 top producing countries are on the decline, and only seven are on a sustained production growth path.

How well have we done worldwide in the recent past with the task of discovering new oil reserves? Since the 1990s there has been a persistent imbalance in the P/D (Production/Discoveries) ratio at the global level. The ratio has been 2, implying that production has outpaced discoveries 2 to 1. In other words, existing reserves are notably being depleted and this is conducive to decline in production capacity. A breakdown of the 135 billion barrels of oil discovered in the past decade is given by country and by region. Only three countries have registered double digit discoveries over the last decade.

Chapter 4

This is by far the most extensive section of this report since it provides an in-depth look at upstream oil field developments – past, current, and projected – for each of the 31 top oil producing countries, and on a lesser scale for six emerging oil producing countries. The analysis includes: 1) *trends* in discoveries and production, 2) *general* condition of the top fields in the country, 3) *consumption*, export capability, and 4) *most* importantly, the scope and scheduling of major upstream projects expected to come online by 2016. These projects provide the volumes of existing proven undeveloped reserves (PUDs) expected to go on stream in the next five years. Both EURs (evaluated in the previous chapter) and PUDs are the foundation of our production capacity model and must be well established before embarking on the forecasting phase of this study. What are modeled are the PUDs and not the production capacity of the upstream projects as

such. The use of the latter disregards the physics of decline and depletion in oil fields and consequently leads to highly overstated projections – a more than common error in most outlooks.

Chapter 5

This chapter is all about the development of crude oil-quality outlooks for the 31 top producing countries and the seven producing regions through 2025, and globally through 2030. The physics based analytical production model used in this study, and outlined in the Appendix, is used to first history-match the production data over the past life (which are as long as 90 to 110 years for the producing regions) of the entity (region or country) being analyzed, in order to establish its individual specific parameters. Once a satisfactory match is achieved the model is then used to project the resultant production profile over the desired time frame, in this case through 2025. These projections include the impact of new reserves (PUDs) corresponding to the upstream projects expected to go on stream in the next five years. Unconventional oil and how it is handled in the model is also discussed. The resulting country outputs are subsequently segregated into light, medium, and heavy oil streams based on the actual crude grade-distribution of the major producing oil fields in each country. Summary outlooks are given for each country by region, by oil grade distribution, and at five-year intervals through 2025.

Regarding the global outlook, three scenarios were considered based on uncertainties broadly associated with yet-to-develop known technical reserves (in contrast to proven reserves), and yet-to-find reserves over the medium term. A bandwidth of 200 billion barrels of most likely reserves was assumed to cover these unknowns; this results in a spectrum of most probable outputs which is more realistic than just a single outlook. The results are presented both graphically and summarized by scenario, at five-year intervals through 2030.

The fact that individual outlooks for 31 countries, for seven oil producing regions, and globally all come together coherently is ample testimony to the reliability of the results and validity of the forecasting methodology used in this study.

The report “Comprehensive Assessment of World Crude Oil Supply Through 2030” includes 104 maps, charts, and tables such as the examples below.

Table 1-2A Top Oil Producing Countries with Outputs ≥ 1 mb/d
Production, Consumption, Refining Capacity, Crude Oil Quality

2010

million barrels/day (mb/d)

	Production		Consumption		All Liquids	Refining Capacity				Oil Quality	
	Crude Oil	All Liquids	All Liquids	Imports	Exports	Crude Oil	Catalytic Cracking	Thermal Cracking	Reforming	API Gravity	Sulfur wt. %
North America	10.82	16.10	23.53	7.43		21.31	6.57	0.16	4.18	30.10	1.81
Canada											
Mexico											

Table 2-2 World's Top Producing Oil Fields

Discovery Dates, Production, Oil Quality

2009

	Oil Field, Discovery Date	Production, 1000 b/d	API	Sulfur, wt %	Light/Heavy - Sweet/Sour
North America		10,541	30.1	1.81	Medium-Sour
Canada					

Table 4-1 Crude Oil Production, Reserves, Oil Quality: Top Producing Countries

2010

	Production			Reserves, Bbo				Crude-Quality		
	Rate mb/d	Cumulative Bbo	Growth/Decline	Remaining Reserves		EUR	PUD	API Gravity	Sulfur wt. %	Light/Heavy-Sweet/Sour
				BP	EIA					
North America	10.82	267	-	74	39	355*	11	30.1	1.81	Medium-Sour
Canada										
- Traditional Oil fields										

Table 5-7 North America Regional Crude Oil Outlook by Country through 2025

mb/d

	2010	2015	2020	2025
Canada	2.73	3.03	3.19	3.26
Mexico				
USA				
Total Region				

Table 5-8 North America Regional Crude Oil Quality Outlook through 2025

mb/d

	Light	Medium	Heavy	Total
2010	1.84	5.62	3.35	10.81
2015				
2020				
2025				

Rafael Sandra, PhD

Dr. Sandra graduated cum laude in petroleum engineering from the University of Tulsa and received his Ph.D. from Penn State University. He headed the petroleum engineering department at the Universidad de Oriente in Venezuela and later was the Ford Foundation Professor in the Graduate School of petroleum engineering at the Universidad Nacional of Mexico. Dr. Sandra and his professor from Penn State, Dr. Ralph Nielsen, published *Dynamics of Petroleum Reservoirs under Gas Injection*, Gulf Publishing, 1974, a book used extensively in petroleum engineering courses around the world.

In 1974 he founded a Caracas-based engineering company, ITS Servicios Tecnicos. During his 30-year tenure as President and CEO, ITS provided the oil and gas industry a wide range of technical services and products, including project management, reservoir engineering, geology, seismic processing, E&P Data management and business archiving. ITS carried out projects in several countries around the world including the US, Chile, Pakistan, Trinidad and Tobago and Venezuela. During this time Dr. Sandra served on the Board of Joint Venture Alliances with international companies from the United States, Great Britain, and France.

Today Dr. Sandra is President of IPC Petroleum Consultants, Inc., a Tulsa-based international petroleum consulting firm that specializes in oil and gas reserves appraisals and risk analysis for international upstream petroleum investments. He is very active giving seminars, workshops, and speaking on the reserves theme around the world.

He is a life member of the Society of Petroleum Engineers and member of the Editorial Advisory Board of the forthcoming Petroleum Encyclopedia, of the Board of The Open Petroleum Engineering Journal, and of the UN Ad Hoc Group of Experts on Fossil Resources. Dr. Sandra has published over 30 technical papers, a dozen within the last five years, which include a 2011 eReport: *"An In-Depth View of Future World Oil & Gas Supply"*. His latest publications cover areas such as risk analysis for international upstream petroleum investments, appraisal of global oil and gas reserves, development of algorithms for estimating the production capacity of new oil fields, global offshore oil reserves potential, assessment of global oil and gas resources and their potential for enhanced oil recovery. Some of these articles have been featured in CNN Money and PetroleumWorld.com. They are available on IPC's website at www.ipc66.com.



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For more information about this report, call PennEnergy Research at 1-800-345-4618, or 918-832-9267. Or search for "Crude Oil Supply" at www.PennEnergyResearch.com.