

Notes and References

Chapter 1—The Origin of Oil

1. See Issue 1 TTNRG (2004) – Why does Trinidad and Tobago have Oil? By Wajid Rasheed. (www.ttnrg.com)
2. Well known fact that the ‘low-hanging fruit’ or easy-to-produce reserves in land and shallow waters have been well characterised and produced.
3. The majority of world’s oil is located in the Tethyan Belt, lying between the equator and mid northern latitudes; and running from Venezuela through the Middle East to China and Indonesia. Tethyan petroleum systems are characterised by facies deposited in tropical environments such as carbonate and evaporites, and prolific source rocks laid down in warm lakes and shallow epic seas. However, about a third of global petroleum is in the mid to high northerly latitudes of the Boreal Realm. Though some petroleum systems rely on Palaeozoic source rocks originally deposited in low paleo-latitudes (e.g. Late Devonian shales of Timan-Pechora Basin), most are sourced from marine Jurassic-Cretaceous shales deposited in restricted rift basins in high paleo-latitudes. These include the world class source rocks of the Neocomian of the North Slope of Alaska and the Late Jurassic of the North Sea, Eastern Canada, and West Siberia. See Bradshaw Marita et al Oil from the South.
4. See Sedimentation in standard geology texts or country geological surveys such as the British Geological Survey.
5. Not just for these reasons but also because carbonates hold much of future reserves.

6. See Issue 1 TTNRG (2004) – Naparima Formation which is the source rock is easily visible in Naparima Hill, Trinidad and Tobago. See AAPG Explorer June 2003 Long studied outcrops in Spain that may hold secrets to understanding deepwater reservoirs are providing new clues, thanks largely to new 3-D laser technologies.
7. Oil shales did not make it through the ‘Window’ for the Formation of Oil and Gas. Oil shale/sands were not subjected to the depth, pressure and temperature necessary to form crude oil. Therefore, their hydrocarbon content varies between that of coal and crude oil. Extraction efficiency depends on differing factors but generally 1 barrel of oil requires 1.5 to 2 tonnes of rock or sand. The total global resource of oil shales is order of magnitude greater than crude oil reserves. But extracting the energy value of oil shale is only valid at US \$50 to \$70. The industry is working on ways to reduce shale oil extraction costs.
8. See Horizontal Well Technology, Sada Joshi, p 49 Reservoir Engineering Concepts ISBN 0878143505. Drop a stone in a calm pond. As soon as the stone is dropped in the pond, one can see circular waves going outward. A similar phenomenon occurs when a well is put on production in a given drainage area. The pressure disturbance or loss is felt initially at the wellbore and it will take time before fluids furthest from the well start migrating to the well and as time progresses average reservoir pressure decreases. See Reservoir Engineering texts for detail of primary reservoir pressure curves and bottom-hole pressure.
9. See Saudi Arabia Oil and Gas Magazine Issue 8 2008 - Ghawar, Saudi Aramco. (www.saudiarabia-oilandgas.com).
10. See Pirson S.J., 1950, Elements of reservoir engineering: McGraw-Hill.
11. Economic conditions are moving targets dependent on oil prices and production technology. Finding and lifting costs themselves vary, ultimately it is the oil price and the cost of production technology that determines what is cost effective. Nonetheless an average of 65% of conventional resources are left underground.
12. Surveys help reduce drilling risk.
13. See Diagenesis of Carbonate Rocks: Cement-Porosity Relationships Friedman ISBN: 0918985366.
14. In drilling wells sub-salt GOM and Brazil the occurrence of impermeable Anhydrite and Shale beds is commonplace.
15. Cores are just one of the geologist’s characterisation tools.
16. HSE will be statutory requirements set by lease agencies such as the Minerals Management Service (MMS) in the offshore US OCS or environmental authority IBAMA in Brazil.
17. Petroleum Geology and Resources of the Dnieper-Donets Basin, Ukraine and Russia, by Gregory F. Ulmishek. U.S. Geological Survey Bulletin 2201-E.
18. The Drilling & Development of the Oil & Gas Fields in the Dnieper-Donetsk Basin, by V. A. Krayushkin, T. I. Tchabanenko, V. P. Klochko, Ye. S. Dvoryanin Institute of Geological Sciences and J. F. Kenney Russian Academy of Sciences.

Chapter 2—Reserves, Peak Oil and Medieval Maps

1. See Harts E & P Sept 2002 Drilling Column. 'Manage your tapped resources' by Wajid Rasheed. Discussion on industry cycles and reserves acquisition.
2. The OPEC Statute requires OPEC to pursue stability and harmony in the petroleum market for the benefit of both oil producers and consumers. To this end, OPEC Member Countries respond to market fundamentals and forecast developments by co-ordinating their petroleum policies.
3. See Booklet: What is OPEC? Production regulations are simply one possible response. If demand grows, or some oil producers are producing less oil, OPEC can increase its oil production in order to prevent a sudden rise in prices. OPEC might also reduce its oil production in response to market conditions. Public Relations & Information Department, OPEC Secretariat, Obere Donaustrasse 93, A-1020 Vienna, Austria. Tel: +43 1 211 12-279, (www.opec.org).
4. See Oil and Gas Reserves Committee (OGRC) "Mapping" Subcommittee Final Report – December 2005 p 14, Russian Reserves Classification based on Russian Ministry of Natural Resources (RF-2005).
5. Ditto p 16 Norwegian based on Norwegian Petroleum Directorate (NPD-2001).
6. There are as many as 7 different reserves classification systems in practice.
7. The SPE is seeking to overhaul and standardize current classification methods.
8. The Industry is lobbying the SEC for a rule change.
9. E & P technology clearly make reserves more accessible. The problem is at what cost? The issue is not simply related to oil price v technology cost but certainly more account should be made of the role of technology and reserves classifications.
10. This is what determines asset valuation and cash flow.
11. Standard knowledge in the industry.
12. See SPE (OGRC) "Mapping" Subcommittee Final Report Definition of Proved Reserves page 31.
13. Ditto p 14 Russian Classifications.
14. Ditto p 16 Norwegian Classifications.
15. Ditto.
16. Baker, R.A., Gehman, H.M., James, W.R., and White, D.A., 1984, Geologic field number and size assessments of oil and gas plays: American Association of Petroleum Geologists Bulletin, v. 68, no. 4, p. 426–437.
17. Plays and Concessions—A Straightforward Method for Assessing Volumes, Value, and Chance, P. Jeffrey Brown and Peter R. Rose

18. U.S. Geological Survey World Petroleum Assessment 2000—Description and Results By USGS World Energy Assessment Team.
19. Communications with Dr Colin Campbell, one of the leading voices of Peak Oil.
20. Optimists.
21. This is the Author's own view. The three Ps are commonly recognized measures of probability of production.
22. Clearly, at some point Antarctica will be opened up for E & P. See The Petroleum Potential of Antarctica, Macdonald, David University of Aberdeen, UK.
23. Remote projects that I have worked on i.e. Brazil Foz de Amazonas, Amazon, have had the lack of infrastructure create major problems for planned operations and unplanned events.
24. From both IOC and NOC data.
25. These are not replacement costs but historic costs. Report on UK Sector NWECS 2000 Wajid Rasheed.
26. See Brazil Oil and Gas Issue 1, Interview with Petrobras International Executive Manager Joao Figueira (www.braziloilandgas.com).
27. See The Tectonic and Paleogeographic Context of Madagascan Petroleum Systems, Hoult et al Models of a pre-Jurassic Gondwana fit range from a palaeo location for Madagascar off Mozambique (Flores, 1970) to that of Reeves et al. (2004) who, like most current authors, place Madagascar off the Kenya/Somali coast. The precise tightness of fit is still a matter of debate.
28. See AAPG Explorer Magazine Nov 2002 Kathy Shirley.
29. See Brazil Oil and Gas Issue 11 p 6 Tupi's recoverable volume of 5 to 8 billion barrels of oil equivalent may place Brazil in the select group of petroleum exporting countries (www.braziloilandgas.com/issue10). In 2008, Petrobras announced new oil discoveries in the Santos, Espírito Santo, Campos, and Jequitinhonha Basins. In the Santos Basin pre-salt layer alone, the company estimates recoverable volumes of 9.5 billion and 14 billion barrels of oil and gas in barrel equivalent in the Tupi, Iara, and Jupiter areas. In September 2008, the Company started producing in the pre-salt in the Espírito Santo sea, in the Jubarte Field, located in the Campos Basin.
30. The Identification of The Depositional Environments Of The Cruse, Forest And Morne L'Enfer Formations In The Southern Half Of The Gulf Of Paria, Trinidad, West Indies Curtis Archie, PetroTrin.
31. Oil from the South: Mesozoic Petroleum Systems, Proven and Potential, in Mid to High Southerly Latitudes Bradshaw, Marita et al. Is there a corresponding belt of petroliferous basins in the southern hemisphere? Notable oil provinces do occur in mid to high southerly latitudes. Oil source rocks include marine Early Cretaceous shales (San Jorge and Magallanes/Austral basins, South America; Bredasdorp Basin, South Africa) and Late Cretaceous to Eocene coaly sediments (Gippsland Basin, south-east Australia; Taranaki Basin, New Zealand). Frontier Mesozoic rift basins occur in offshore East Africa, along Australia's southern margin (Bight and Mentelle basins), on the Lord Howe Rise,

offshore New Zealand and in the Falklands. Regional studies of the shared history of Gondwana breakup and paleoclimatic and environmental reconstructions can guide exploration in these frontier areas.

32. See page 230 *The Prize: The epic quest for Oil, Money and Power* Daniel Yergin Publisher: Simon and Schuster (Jan 01 1993) ISBN: 0671799320.

33. AAPG Explorer, October 2008, Independents Find Africa Success.

34. Gas Beckons in Deep Shallows. Louise Durham Gas exploration to depths of 30,000 ft.

35. The Discoverer Enterprise of Transocean is the first ultra-deepwater drillship with dual activity drilling technology, which aims to reduce the cost of an ultra-deepwater development project by up to 40 percent. Two full-sized rotary tables are designed into a drill floor more than twice as large as a conventional one.

36. The industry is looking at ultra-deepwater as 3,000 m.

37. Harts E & P Mar 2002 Drilling Column, by Wajid Rasheed. 'Small companies and tangled thickets'.

38. See *The Medieval Map* page 45.

39. Campbell, Peak Oil ... Hubberts Peak: The Impending World Oil Shortage Deffyes.

40. Author's notes on acreage in emerging markets.

41. Lifting costs EPRasheed.

42. Idem.

43. *The End of Oil: On the Edge of a Perilous New World* Roberts Publisher: Houghton Mifflin; (May 15, 2004) 400 pages ISBN: 0618239774.

44. AAPG Morocco substrate.

45. Deepwater plays are among the most complex, high cost projects requiring large capital investment therefore favouring large IOCs.

46. Expand your mind, Harts E & P 2004 Wajid Rasheed.

47. Petrobras evolution offshore.

48. *The Oil Factor: How Oil Controls the Economy and Your Financial Future* Donna & Stephen Leeb Published: February, 2004 ISBN: 0446533173.

49. *Coming Oil Crisis*, Campbell Publisher: Multi-Science Publishing Co. Ltd.; (April 1, 2004) 210 pages ISBN: 0906522110.

50. *Hubberts Peak: The Impending World Oil Shortage* Deffyes Publisher: Princeton University Press; (August 11, 2003) 224 pages ISBN: 0691116253.

Chapter 3—What's In a Wet Barrel?

Readers note; reservoir and reservoir fluid characteristics are well covered in industry texts. Physical and chemistry texts provide the background to PVT behaviour, single and multi phase fluid flow:

1. Crude oil volumes are still reported in barrels and in some cases in tonnes. However, the number of barrels contained in a tonne varies according to the type and specific gravity of the crude involved. An average number would be around 7.33 barrels per ton. Surface oil is reported at stock-tank (st) conditions, with volumes in cubic metres (m^3) or barrels [stb, or (st)bbbl].

2. API What a barrel of crude oil makes. API Factsheet.

3. See Petrobras Technology Harts E & P, June 2003 p 45 for heavy oil definition below 19°API.

4. TTNRG Nature's Best Wajid Rasheed.

5. Pricing differential is due to higher proportion of heavier and sourer (high sulphur) crudes that relative to light sweet production. More than half the world's produced oil is heavy and sour in quality and this proportion is expected to increase. This depends on the crude oil's molecular structure and sulphur content. The oil will be classified accordingly and priced using reference crudes. Some of the common reference crudes are: West Texas Intermediate (WTI), Brent blend from the East Shetland Basin of the North Sea. Dubai-Oman, used as benchmark for Middle East sour crude oil flowing to the Asia-Pacific region, Tapis (from Malaysia, used as a reference for light Far East oil), Minas (from Indonesia, used as a reference for heavy Far East oil), The OPEC Reference Basket, a weighted average of oil blends from member countries.

6. The compositions of different crudes are measured and published in assays. Refining engineers use assays to decide which crudes will be required to formulate products.

7. API 5 RP 44 Sampling Petroleum Reservoir Fluids Proper management of production from a natural gas or petroleum reservoir can maximize the recovery of the hydrocarbon fluids (gas and oil) originally in the reservoir. Developing proper management strategies requires accurate knowledge of the characteristics of the reservoir fluid. Practices are recommended herein for obtaining samples of the reservoir fluid, from which the pertinent properties can be determined by subsequent laboratory tests.

8. For gas wells, the inverse ratio is sometimes used and the liquid-gas ratio is expressed in barrels per million m^3 (or million cubic feet).

9. Formation, Removal, and Inhibition of Inorganic Scale in the Oilfield Environment Author: Wayne W. Frenier and Murtaza Ziauddin ISBN: 978-1-55563-140-6. See also Scale formation RP 45 Analysis of Oilfield Waters 3rd Edition/August 1998.

10. Refining costs Sulphur Corrosion Control Author: Charles Kirkley See also RP 49 Recommended Practice for Drilling and Well Servicing Operations Involving Hydrogen Sulphide Recommendations include well drilling, completion, servicing, workover, downhole maintenance, and plug and abandonment procedures conducted with hydrogen sulphide present in the fluids being handled. 2nd Edition / May 2001. Further cost is added at the refining stage.

11. The Color of Oil Economides et al. Publisher: Round Oak Publishing Company; (March 1, 2000) 220 pages ISBN: 0967724805.

12. EIA BTU fuel content.
13. See also API Manual of Petroleum Measurement Standards. This manual is an ongoing project, as new chapters and revisions of old chapters are released periodically.
14. Condensates Energy supplies are often quoted in barrel of oil equivalent (boe). The energy contained in 6000 scf (170 m^3) of gas is about equivalent to that in one barrel of oil (0.16 m^3), so for an oil with a gas-oil ratio of 1500 scf/bbl ($266 \text{ m}^3/\text{m}^3$), 25% of the energy from the reservoir is contained in the produced gas. Thus for black oils about 10 % of the produced energy is in the gas, whereas for the gas condensate field about 75% of the energy is produced as gas. For this reason condensate reservoirs are not produced for the sake of the liquids only. A gas field of size 0.6 trillion scf is equivalent to an oil field of around 100 mmbbls.
15. See Advanced Reservoir Engineering Author: Tarek Ahmed and Paul McKinney ISBN: 0-7506-7733-3.
16. Saudi Arabia Oil and Gas Issue 4 The Carbonate Challenge (www.saudiarabioilandgas.com).
17. The behaviour of reservoir fluids is based on the laws of physical chemistry for perfect gases and the phase changes in gas-liquid systems.
18. The Flow of Complex Mixtures in Pipes, 2nd Edition, G.W. Govier and K. Aziz. Thirty-five years after its first publication, remains a fundamental resource, providing a unified approach to all types of complex flow.
19. Lab Crude Samples McCabe, Warren L.; Smith, Julian C.; Harriot, Peter (2005), Unit Operations of Chemical Engineering (seventh ed.), New York: McGraw-Hill, pp. 737-738, ISBN 0-07-284823-5.
20. API 5 RP 44 Sampling Petroleum Reservoir Fluids Proper.
21. SPE 102854 Performance Appraisals of Gas/Oil Separation Plants by S. Kokal, SPE, and A. Al-Ghamdi, SPE, Saudi Aramco.
22. If the field is communication similar datum corrected pressures will be found as average reservoir pressure drops.
23. Fluid Flow & Heat Transfer In Wellbores A.R. Hasan and C.S. Kabir.
24. The properties of crude oil and hydrocarbon gases have been extensively studied over the past several decades and many useful tables and correlations can be found in prior work e.g. charts (Dawe and Bradley 1987, McCain 1990).
25. The compressibility of oil is not entirely pressure dependent. The reported density of the oil is almost always that of the stock-tank oil not the reservoir oil, although reservoir oil density varies with pressure due to the associated effect of the gas in solution, which varies with pressure.

An accurate knowledge of Pb (bubble point pressure) is important when producing a reservoir. It is the reservoir pressure below which gas comes out of solution so that production can become more complicated. Gas affects oil recovery and production rates, well performance, and vertical pressure-loss calculations.

26. The oil-formation volume factor, Bo. When the pressure is released to below Pb, gas comes out of solution. As the oil is produced the drop in pressure and temperature in the wellbore causes the oil to shrink.
27. The oil density, ρ_o .
28. The API gravity (the equivalent oil density at stock tank conditions).
29. When the reservoir pressure drops below Pb, some gas is released from the oil in the formation. The gas-solubility factor, R, is the volume of free gas at standard conditions that is released from that volume of reservoir oil that results in a unit volume of stock-tank oil.
30. There is a great variation in oil viscosity μ_o , from formation oils that are thinner than water to heavy oils, having the consistency of a thick tar. The main effect of pressure ($<P_b$) on viscosity is that gas comes out of solution, and as the gas contains the lighter hydrocarbon molecules, the viscosity tends to increase as pressure drops.

The current version of IUPAC's standard is a temperature of 0°C (273.15°K, 32°F) and an absolute pressure of 100 kPa (14.504 psi).

Standard Conditions are generally 15°C and 1 atmosphere (or sometimes 1 bar) or 60°F and atmospheric pressure (14.7 psi).

Natural gas volumes are reported in standard cubic metres [(s)m³] or standard cubic feet (scf). Quantities of natural gas are usually expressed in cubic feet; a cubic foot is equivalent to approximately 0.028 m³ at standard conditions. However, for reserves valuation, gas is usually expressed in thousands (103) of cubic feet (Mcf), millions (106) of cubic feet (MMcf), billions (109) of cubic feet (BCF) or trillions (1012) of cubic feet (TCF).

Various measurement units are used in the petroleum industry and conversion factors are summarised in the table below.

Crude Oil and Gas Conversion	
1 barrel (bbl)	158.98729 litres
1 barrel	0.15898729 cubic metres
1 standard cubic metre (Scm, Sm³)	6.28981 barrels
1 standard cubic metre	0.84 tonnes of oil equivalent (toe)*
1 tonne	7.49 barrels*
Natural gas	
1 cubic metre	35.31467 cubic feet
1 cubic foot	1000Btu (British thermal unit)**
1 cubic foot	0.028317 cubic metres
* Conversion factors for oil equivalent are calculated from the average calorific value for each petroleum type.	
** Depends on the gross calorific value (GCV) of the gas.	
(Source StatoilHydro)	

“bbl” means barrel(s), “stb” means stock tank barrel(s); “mmbbl” means millions of barrels; “mmstb” means millions of stock tank barrels; “mmscf” and “bcf” means millions and thousands of millions respectively of standard cubic feet. “recovery factor” means the percentage of the quantity of petroleum in place which is considered recoverable.

Chapter 4—The Fall of the Oil Curtain

1. Rice University’s Baker Institute for Public Policy Oil production of the five largest oil companies has declined since the mid-1990s. Oil production for the five largest IOCs fell from 10.25 million barrels a day (b/d) in 1996 to 9.45 million b/d in 2005 before rebounding to 9.7 million d/b in 2006. By contrast, for the next 20 U.S. independent oil firms, their oil production has risen since 1996, from 1.55 million b/d in 1996 to about 2.13 million b/d in 2005 and 2006.
2. Little did Cardenas know what train of events he would set off.
3. Timeline OPEC: Origins & Strategy 1947–1973 Editor: A.L.P. Burdett.
4. “O petróleo é nosso” (“The oil is ours”) was the battle cry vocalized by students and workers on the streets of Brazil during the 40’s and 50’s. On October 3, 1953, President Getúlio Vargas created Petróleo Brasileiro (Petrobrás), a state monopoly in charge of E & P, refining and distributing oil in the country. See *Offshore Engineer – Walks Tightrope*, May 2003. See also Harts E & P Dec 2003 ‘Sustainable growth works’ Interview with Petrobras E & P Director, Estrella.
5. Prize: The epic quest for Oil, Money and Power Daniel Yergin Publisher: Simon and Schuster (Jan 01 1993), ISBN: 0671799320, Race begun.
6. Anthony Sampson The Seven Sisters: The great oil companies & the world they shaped.
7. Prize: The epic quest for Oil, Money and Power Yergin Publisher: Simon and Schuster (Jan 01 1993) ISBN: 0671799320.
8. Oil and Politics in Latin America, Nationalist Movements and State Companies George Philip and Knight, Alan ISBN: 9780521030700.
9. Mexico’s petroleum industry was taken back from the “Seven Sisters” in March 1938 by then-President Lazaro Cardenas, a revolutionary nationalist act.
- 10, 11, 12. F Parra, Oil Politics: A Modern History of Petroleum (IB Taurus, London 2004).
13. The Large International Firm in developing countries Allen and Unwin London 1968.
14. The late Professor Edith Penrose wrote in a book review in *The Economic Journal* in June 1963 (page 322): ‘In the first place... the companies are truly international in outlook only to a limited extent; they are Western and their interests are firmly linked to those of Western Powers. Secondly, the people of the crude-oil producing countries do not believe that the companies act independently of governments and will not in fact absolve the “imperialist” powers from responsibility for company actions’.
15. See OPEC History.

16. Texas Railroad used by Tariki and Perez.
17. This is best displayed by modern NOCs such as Petrobras, CNPC and StatoilHydro.
18. Some commentators have ascribed various comments to Perez. No doubt whatever Perez said it would not have been polite.
19. See OPEC History 1st Resolution.
20. Anthony Sampson *The Seven Sisters: The great oil companies & the world they shaped*.
21. See Penrose and Sampson for rates of return for IOCs.
22. See Penrose *The Unravelling of IOC concessions*.
23. See OPEC recent history on website.
24. This remains the highest peaking of oil prices.
25. See OPEC recent history on website.
26. See Oxford Energy Comment, July 2000 *Managing Hydrocarbon Resources in a New Era: The Call from Algeria*, By Ali Aïssaoui for a modern viewpoint.
27. This was widely covered by the worldwide press.
28. See the Gas ventures in Saudi Arabia and the Service contracts in Mexico.
29. Refers to the US \$147 peak in mid 2008.
30. OPEC is always widely covered by the press.
31. See EIA IEO 2008 reference case.
32. See Penrose on the IOC upper hand.
33. See commentary of BP in Iran 'its principality of production'.
34. Enrico Mattei by Nico Perrone, Bologna—Il Mulino, 2001.
35. Harts E & P Sept 2002 Drilling Column. 'Manage your tapped resources'. Discussion on industry cycles.
36. A decade ago the Oil price was US \$10 bbl.
37. Cost reduction by Wajid Rasheed NWECS report summed by the Arco motto 'No decline in 1999'.
38. Cost reduction by Wajid Rasheed NORSOK NWECS report.

39. Financial Analysis of Mergers for shareholders.

40. See Rice University's Baker Institute for Public Policy. Exploration spending of the five largest IOCs has been flat or lower in the aftermath of OPEC's reinvigorated effort to constrain market supply in 1998. Given the uptick in costs of material, personnel and equipment such as drilling rigs, the five largest IOCs have cut spending levels in real terms over the past 10 years. This trend appears, however, to be easing, with exploration spending by the five increasing IOCs rising by 50 percent in 2006 over 2005.

Instead of favouring exploration, the five largest IOCs used 56 percent of their increased operating cash flow in 2006 on share repurchases and dividends. They have also increased spending on developed resources, presumably to realise these assets quickly while oil prices are high.

41. See Harts E & P Dec 2003 'Sustainable growth works' Interview with Petrobras E & P Director, Estrella.

42. See In the Shadow of a Saint, by journalist Ken Wiwa for an alternate viewpoint on the Niger Delta.

43. Corporate governance equally applies for individuals. Being hired by any service or oil company involves numerous due diligence and non-conflict forms.

44. The international aspect really applies to the NOCs that have high cost reserves. Rice University's Baker Institute for Public Policy. Wall Street investors increasingly recognize these new exploration investment trends and the value of shares of NOCs have risen at a much faster rate than those of the largest IOCs.

45. Norway Oil and Gas Issue 1 (www.norwayoilandgas.com).

46. See Saudi Aramco Annual Report 2006 Rabigh.

47. Idem.

48. Idem.

49. PdVSA Annual Report 2006.

50. See PdVSA Annual Report 2006 Petro Caribe.

51. PdVSA Annual Report 2006.

52. Harts E & P Dec 2003 'Sustainable growth works' Interview with Petrobras E & P Director, Estrella.

53. Petrobras and Self-sufficiency. The Zero Fome campaign was widely by the Brazilian press.

54. Brazil Oil and Gas Issue 4 interview with Petrobras USA President Renato Bertani.

55. Idem.

56. USA President Renato Bertani Monolithic Offshore Engineer, by Wajid Rasheed.

57 Norway Oil and Gas (www.norwayoilandgas.com)

58. See Penrose.

59. The Harts E & P Mar 2002 Drilling Column. 'Small companies and tangled thickets'.

60. Black Blessing—Saudi Arabia Oil and Gas Issue 5. See Author's Interview with OPEC, Chatham House, The Royal Institute of International Affairs, NPD Norwegian Petroleum Directorate. Dubai Media City.

Chapter 5—World Oil and Gas Production

1. BP Statistical Review 2008 page 8.

2. Considering the contributions oil revenues make to GDP

3. Concerns regarding commercialisation and profitability are the main reasons why insufficient refining capacity.

4. The GECF was widely covered in the press.

5. BP Statistical Review 2008 defined as proved reserves.

6. Saudi Aramco Annual Report 2008. For specifics of technologies see editions of Saudi Aramco Journal of Technology.

7. King Abdullah University of Science and Technology (KAUST) is being built in Saudi Arabia as an international, graduate-level research university dedicated to inspiring a new age of scientific achievement in the Kingdom that will also benefit the region and the world. KAUST will be merit-based and will recruit men and women from around the world.

8. BP Statistical Review 2008 page 8.

9. EIA/IEO www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/oil_market_basics/supply

10. BP Statistical Review 2008 page 8.

11. BP Statistical Review 2008 page 11.

12. Rice University Energy Study: Latin America the Orinoco Heavy Oil Belt in Venezuela (Heavy Oil To The Rescue?) Manik Talwani Schlumberger Professor of Earth Science.

13. EIA/IEO www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/oil_market_basics/supply

14. PdVSA Annual Report 2008.

15. BP Statistical Review 2008 page 8.

16. Oil wealth has undoubtedly helped the UAE especially Abu Dhabi secure commercial growth.

17 See Dubai's Strategic Plan

18. BP Statistical Review 2008 page 8.
- 19 See Niger Delta Development Commission Master Plan 2001 which states ‘There have been many attempts and many plans made in the past to improve the lives of the people of the Niger Delta Region of Nigeria. Sadly, each ended with very little to show for the time and resources spent. Therefore it is understandable that the people of the Niger Delta are quite disillusioned with ‘plans’ at this time. The disenchantment of the people notwithstanding, it must be stated that the Niger Delta Master Plan is different in its goals, focus and approach, and will not suffer the fate of the others before it’.
20. Depositional Control on Hydrocarbon Accumulations in Deepwater Nigeria By Xijin (CJ) Liu Conoco Phillips Search and Discovery Article #40226 (2006)
21. Kuwait Petroleum Corporation (KPC) Annual Report 2008.
22. Any number for consumption will be controversial for those who require an explanation see “Scramble to carve up Iraqi oil reserves lies behind US diplomacy,” Observer, October 6, 2002.
23. BP Statistical Review 2008 page 8.
24. Sarir, Sirte Basin, Desert Surprise Then and Now Some Keys to Revisit of Libya Compiled from articles by C. J. Lewis (1990) and R. M. Sanford (1970).
25. Framework for the Exploration of Libya: An Illustrated Summary Compiled by Jingyao Gong.
26. Sonatrach Annual Report 2007.
27. BP Statistical Review 2008 page 8.
28. Idem.
29. Idem.
30. OPEC Annual Statistical Bulletin 2008.
31. EIA IEO 2008 outlook.
32. EIA IEO 2008 outlook states Kazhakstan as exporter to note.
33. The deepwater developments are particularly susceptible to the low oil price environment.
34. Perhaps wider co-ordination is simply due to market forces.
35. See Brazil Oil and Gas Issue 3 – Petrobras and Self Sufficiency (www.braziloilandgas.com/issue3).
36. BP Statistical Review 2008 page 8.
37. OPEC Annual Statistical Bulletin 2008.
38. EIA IEO 2008.

39. This is a well known fact regarding Canadian Tar Sands.
40. There is no doubt regarding OPEC's future importance.
41. BP Statistical Review 2008 page 18.
42. Idem.
43. The Stabilization fund of the Russian Federation was established on January 1, 2004 as a part of the federal budget to balance the books in the event of the oil price falling below a cut-off price, currently set at US \$27 per barrel. Furthermore, the Fund is to serve as an important tool for absorbing excessive liquidity, reducing inflationary pressure and insulating the economy from the volatility of export earnings.
44. Widely reported in the press.
45. Rosneft Annual Report 2008 converted from tonnes.
46. Ditto above.
47. Sakhalin Report 2006.
48. Rosneft Annual Report 2008.
49. GazpromNeft Annual Report 2008.
50. OJSC Noyabrskneftegazgeophysica—Company Profile 2006.
51. Sibneft Annual Report 2005.
52. GazpromNeft Annual Report 2008.
53. Recently Russia is investing more in its Gas infrastructure.
54. Offshore Magazine Feb 1997 RUSSIA Barents Sea still languishing in political limbo Gazprom, Rosshelf, and partners predicting production post-2000 Dev George Managing Editor.
55. Nordstream Facts Newsletter Issue 9/1—2009.
56. Barents Sea field delineated 2008-12-08 StatoilHydro.
57. Idem.
58. CGES Pipeline Advisory Service bulletin No. 23 2006 6th November 2006.
59. Baltic Pipeline System (BPS) was built to transport the crude from fields in Western Siberian, Timan-Pechora and Volga-Urals petroleum provinces to a terminal on the coast of the Gulf of Finland for export. The system includes an existing oil pipeline, which links Haryaga and Usa, trunk pipelines from Usa to Ukhta to Yaroslavl to Kirishi, new trunk pipelines between Haryaga and Usa and between Kirishi the coast of the Gulf of Finland, and finally the new oil export terminal in the city of Primorsk.

60. The Federation of Russian States Oil and Gas Activity and Concession Map—2nd Edition—2007.
61. Sakhalin-1 Project Receives Award for Excellence from International Petroleum Technology Conference Kuala Lumpur, December 3, 2008.
62. The Norwegian Petroleum Directorate is administratively subject to the Ministry of Petroleum and Energy, and advises the Ministry on matters concerning the management of the petroleum resources on the Norwegian continental shelf. The Directorate holds all the important data in connection with the petroleum activity in Norway, including a complete, up-to-date survey of resources, production, costs and other relevant information.
63. BP Statistical Review 2008 page 8.
64. Norway StatoilHydro shareholders.
<http://www.statoilhydro.com/en/InvestorCentre/Share/Shareholders/Top20/Pages/default.aspx>
65. Petter Osmundsen Commitment at home and abroad 30.4.2007 Merging Statoil and Hydro's petroleum business will benefit the international involvement of the new company, since size is significant in this business. But any reduction in activity on the NCS would be a very poor socio-economic outcome for Norway.
66. See Petoro Perspective Sveinun Sletten. The Norwegian government has been involved as an owner from the early days of the country's oil adventure – through Statoil and Hydro. And from 1985 also through the State's Direct Financial Interest (SDFI).
67. The Norwegian Petroleum Directorate shall contribute to creating the greatest possible values for society from the oil and gas activities by means of prudent resource management based on safety, emergency preparedness and safeguarding of external environment.
68. The Research Council for Norway, Funding for Petroleum Research Adviser Tor-Petter Johnsen PETROMAKS.
69. Offshore Magazine April 2002 Norway: NKr 46 billion Snøhvit scheme brings LNG to northern Norway By Nick Tedre, Contributing Editor.
70. StatoilHydro Annual Report 2008.
71. 2000 NWECS Report by Wajid Rasheed.
72. BP Statistical Review 2008 page 8.
73. US Country Analysis Brief of Mexico <http://www.eia.doe.gov/emeu/cabs/mexico.html>
74. US EIA DOE Caspian Sea Analysis Report January 2007.
75. Authors discussion with Kazhak expert.
76. See www.eia.doe.gov/emeu/cabs/Kazakhstan/pdf

Chapter 6—Properties, Players and Processes

1. Land and Leasing ISBN: 0-88698-094-1 PETEX 1984.
2. Well Planned Brazil Oil and Gas Issue 5 Wajid Rasheed.
3. These are generic rules for ease of classification.
4. This will depend on the land owner's priorities.
5. The API Specification Database The American Petroleum Institute Specification Database Software™ provides a knowledge-management toolset for the project engineering team. Facilitates the entire equipment specification process including the entry of process data and design to the final entry of mechanical data sheets and development of the technical bid specification package.
6. Dependent on the oil company and land-owner involved.
7. May vary from lease to lease.
8. Negotiation plays as important a role as the bid.
9. Such as building local content.
10. Such as Brazil, Mexico and Saudi Arabia which all had monopolies.
11. Fundamental to asset management.
12. From the 30 countries I have worked in this is very much the case.
13. Idem.
14. Corporate governance requirements are often stipulated as contractual terms.
15. Also known as in-house engineers.
16. Harts E & P Mar 2002 Drilling Column Wajid Rasheed. 'Small companies and tangled thickets'.
17. Idem.
18. The reassessment of risk and reward seems to have stopped at percentage of value delivered or percentage operational cost.
19. Harts E & P Mar 2002 Drilling Column Wajid Rasheed 'Small companies and tangled thickets'.
20. Although this may change as IOCs seek to differentiate themselves. Shell selects certain start-ups through its technology ventures (STV).
21. Harts E & P Mar 2002 Drilling Column Wajid Rasheed 'Small companies and tangled thickets'.

22. Harts E & P Jun 2004 Drilling Column 'Bundled or bungled services?'. Advocates balanced integrated services contracts.

23. In a low oil price some service companies may prefer to take greater risk. Others would shun this as unthinkable.

Chapter 7—Pregnant Ladies and Fish Bones

1. My first encounter with the 'Pregnant Lady' well profile was with Shell to avoid drilling a highly unstable zone while numerous 'Fishbones' were found in Saudi Aramco. Fishbones are also known as multi-laterals.

2. Seismic Inversion by Mrinal K. Sen, ISBN: 978-1-55563-110-9 Society of Petroleum Engineers.

3. Principles of Petroleum Development Geology by Robert Laudon, ISBN: 0-13-649468-4, Prentice Hall.

4. Seismic reduces but does not eliminate the risk of dry-hole. Dr Drill always has final say.

5. Actual requirements will vary from country to country depending on the environmental or marine authority.

6. The cost increases due to time involved but much higher quality data is acquired.

7. Again seismic will reduce risk but may miss features. Drilling is required to be certain.

8. Originally from 'Well Planned' by Wajid Rasheed Brazil Oil and Gas Issue 4 2005.

9. Theoretical means of course, the well needs to be constructed.

10. This is set by all members of the team.

11. Vertical wells may require a means of directional control due to formation trends or other drilling problems.

12. First oil is notoriously difficult to predict.

13. Abnormal Pressures While Drilling—Origins, Prediction, Detection, Evaluation. Jean-Paul Mouchet and Alan Mitchell, ISBN: 9782710809074 Editions TECHNIP

14. Mud Logging J C Placido et al Brazil Oil and Gas Issue 4.

15. Idem.

16. Pollen and spores are also examined especially as fossils will have been broken up by the drilling process.

17. Many other parameters exist and are dependent on operational need.

18. Certain wireline logging applications have been superseded by LWD.
19. Harts E & P Dec 2003 Drilling Column. This article was written jointly with the late Chris Lenamond 'Downhole Vision'.
20. Idem.
21. Idem.
22. Obviously the problem lies in the time delay between cores being acquired and analyzed.
23. Theoretically cores should be frozen. Although desirable, this is not always possible, especially in desert areas.
24. As with all things in the industry which are oil price driven.
25. Applied Drilling Engineering, Textbook Vol. 2 A.T. Bourgoyne Jr., K.K. Millheim, M.E. Chenever, ISBN: 978-1-55563-001-0.
26. Idem.
27. Society of Petroleum Engineers/Canadian Institute of Mining. Wajid Rasheed Paper 65504 Controlling Inclination in Tight TVD Corridors. Presented at the International Conference on Horizontal Technology, Calgary, Canada, Nov 2001.
28. 'Drilling', American Association of Drilling Engineers, Official publication. Sep 02 'Power steering'. Discusses the Rotary Steerable market.
29. Idem.
30. Well documented across the industry.
31. 'Drilling', American Association of Drilling Engineers, Official publication. Sep 02 'Power steering'. Discusses the Rotary Steerable market.
32. Harts E & P Dec 2002 Drilling Column 'Deepwater faces its own challenges'.
33. Applied Drilling Engineering, Textbook Vol. 2 A.T. Bourgoyne Jr., K.K. Millheim, M.E. Chenever, ISBN: 978-1-55563-001-0.
34. Harts E & P Oct 2004 Drilling Column. Expand your mind.
35. Keynote Address, Society of Petroleum Engineers Annual Technical Conference, Houston, USA. 2004 by Wajid Rasheed 'Reaching the potential of the Monobore: Intelligent tubulars, drill-pipe and underreamers.
36. Harts E & P 2002 Wajid Rasheed 'Intelligent wells linked by satellite'.

Chapter 8—Extreme E & P

1. Harts E & P Dec 2002 Drilling Column 'Deepwater faces its own challenges'.
2. 'Drilling', American Association of Drilling Engineers, Official publication. Sep 02 'Power steering'. Discusses the Rotary Steerable market.
3. Harts E & P Mar 2004 Drilling Column 'Deepwater drilling challenges'. Underreaming.
4. These types of contingencies can rapidly increase the costs of deepwater wells. See also RP 54. Occupational Safety for Oil and Gas Well Drilling and Servicing Operations. Includes procedures for promotion and maintenance of safe working conditions for employees engaged in rotary drilling operations and well servicing operations, including special services. Applies to rotary drilling rigs, well servicing rigs, and special services as they relate to operations.
5. Notes from Arctic drilling expert John Lewis ASRC.
6. Harts E & P May 2003 Drilling Column "Razor sharp drilling". Simplify wells.
7. Notes from Arctic drilling expert John Lewis ASRC.
8. Petrobras Technology Bulletin 2006.
9. Petrobras Technology Bulletin 2006.
10. Petrobras E & P Technology Harts E & P.
11. Enhanced Oil Recovery, Textbook Vol. 6. by Don W. Green and G. Paul Willhite ISBN: 978-1-55563-077-5, Society of Petroleum Engineers 1998.
12. Petrobras Technology Bulletin 2006.
13. Personal experience of BP's drilling of Rebeca and Reki exploratory wells offshore North West Brazil.
14. As well as service company input.
15. See Petrobras E & P Technology Harts E & P PROCAP section.
16. Along with water depth the distance from shore or facilities will dictate costs.
17. Harts E & P Dec 2002 Drilling Column 'Deepwater faces its own challenges'.
18. See Petrobras Technology Bulletin June 2006.
19. API TR1 Cement Sheath Evaluation Provides the current principles and practices regarding the evaluation and repair of primary cementations of casing strings in oil and gas wells. Cement bond logs, compensated logging tools, ultrasonic cement logging tools, and borehole fluid-compensated logging tools are covered.

20. See Petrobras PROCAP 3000.
21. StatoilHydro Barents Sea E & P.
22. In 2007 Sakhalin Energy produced above 12.4 million barrels of oil from the Molikpaq platform. This exceeded the 2006 production by some 800,000 barrels.
23. API Bull 5C2 Performance Properties of Casing, Tubing, and Drill Pipe Covers collapsing pressures, internal yield pressures, and joint strengths of API casing, tubing, and drill pipe.
24. Harts E & P Mar 2004 Drilling Column Wajid Rasheed 'Salt Challenges'.
25. See Petrobras E & P Technology Harts E & P PROPES section.
26. Idem.

Chapter 9—Mature Fields

1. Enhanced Oil Recovery, Textbook Vol. 6. by Don W. Green and G. Paul Willhite ISBN: 978-1-55563-077-5, Society of Petroleum Engineers 1998.
2. For details of reservoir gas injection and wellbore artificial lift see Petrobras Technology Harts E & P June 2003.
3. These are general figures and are illustrative only. Significant variations occur in practice.
4. Case Study based on information sourced from SPE papers written by Farid Shecaira, Eduardo Faria and other Petrobras sources.
5. Reservoir Engineering Aspects Of Waterflooding Monograph Vol. 3 ISBN: 978-0-89520-202-4 Society of Petroleum Engineers.
6. Thermal Recovery Monograph Vol. 7 by Michael Prats ISBN: 978-0-89520-314-4 Society of Petroleum Engineers, 1986.
7. Modelling future behaviour covers data entry.
8. Fluid samples will be as representative as possible of the reservoirs.
9. This can be an ongoing process accompanying the lifecycle of the field.
10. Petrobras E & P Technology June 2003 Harts.
11. See PRAVAP Petrobras Advanced Oil Recovery Program.
12. Petrobras E & P Technology June 2003 Harts.
13. SPE 65589 Remotely Acidizing Satellite Wells by E. P. Da Motta, C. C. M. Branco, F. S. Shecaira, Petrobras Source SPE International Symposium on Oilfield Chemistry.

14. SPE 69474 Using Tracers to Characterize Petroleum Reservoirs: Application to Carmopolis Field, Brazil by Maria Aparecida de Melo, Carlos Roberto de Holleben, Alcino Resende Almeida, Petrobras R & D Centre.
15. Variations on hydrophilic gel include mechanical inflow control devices with hydrophilic membranes.
16. Both from a light oil and carbonate reservoir perspective.
17. Petrobras presentation on development strategy.
18. Tight gas reservoirs have become a major front in the US and Canada.
19. See Petrobras PRAVAP.
20. SPE 112160 The Fazenda Alegre Journey into Intelligent Energy—Lessons Learned From a Successful Holistic Approach of People, Process, and Technology Aligned to Business Strategy and Results Author W.L. Vinturini, G.B. de Castro, and J.H.S. Crespo, Petrobras, and J.R. Albernaz, M.A.S. Lopes, and A. Valadares, Accenture.
21. Petrobras E & P Technology Harts June 2003.
22. SPE 94898 Evaluation of Polymer Injection Projects in Brazil. Authors M.A. de Melo, C.R.C. de Holleben, I.P.G. da Silva, A. de Barros Correia, G.A. da Silva, A.J. Rosa, A.G. Lins and J.C. de Lima, Petrobras.
23. Petrobras E & P Technology Harts June 2003.
24. Idem.
25. Reservoir Engineering Aspects Of Waterflooding Monograph Vol. 3 ISBN: 978-0-89520-202-4 Society of Petroleum Engineers.
26. See Pravap.
27. Petrobras E & P Technology Harts June 2003.
28. Idem.
29. Reinjection is the ideal solution.
30. This is the Life of Complex Seismic (LoCS).
31. Value of Information for a 4D-Seismic Acquisition Project by P.R. Ballin, SPE, G.S. Ward, C.V. Whorlow, and T. Khan, BP Trinidad and Tobago LLC Source SPE Latin American and Caribbean Petroleum Engineering Conference, 20-23 June 2005, Rio de Janeiro, Brazil.
32. SPE 99948 Integrated Multizone Low-Cost Intelligent Completion for Mature Fields H.L. da C.P. Pinto, M.F. Silva Jr., R.G. Izetti, and G.B. Guimarães, Petrobras.

33. SPE 94705 Produced Water Reinjection in Petrobras Fields: Challenges and Perspectives Author C.J.A. Furtado, A.G. Siqueira, A.L.S. Souza, A.C.F. Correa, and R.A. Mendes, Petrobras.
34. SPE 104034 New Life for a Mature Oil Province via a Massive Infill Drilling Program J.G. Flores, SPE, and W. Gaviria, SPE, Schlumberger, and J. Lorenzon, SPE, J.L. Alvarez, and A. Presser, Petrobras Energia S.A.
35. Petrobras EP Technology Supplement Brazil Oil and Gas Issue 7.
36. Idem.
37. Petrobras EP Technology Supplement Brazil Oil and Gas Issue 7 Seismic throws up array of applications.
38. Most oil companies have similar seismic visualisation rooms.
39. At the time Marlim was the largest acquisition.
40. The models are corrected and validated with field data.
41. Cost Effective Horizontal Drilling in the Troll Field Through use of State of the Art Technology and Optimal Operations by Henriksen, N., Storegjerde, D., Norsk Hydro A/S SPE/IADC 1997.
42. Idem.
43. Troll West Oilfield Development—How a Giant Gas Field Became the Largest Oil Field in the NCS through Innovative Field and Technology Development by Richard Dyve Jones, StatoilHydro AS, Erland Saeverhagen, Arve K. Thorsen, and Sveinung Gard, SPE, INTEQ IADC/SPE 2008.

Chapter 10—Pipelines and Tankers

1. RP 1111 Design, Construction, Operation, and Maintenance of Offshore Hydrocarbon Pipelines 3rd Edition / July 1999.
2. This includes animal and plant life surrounding the pipeline.
3. Projects and Construction of New Oil and Gas, Pipelines in Brazil, Breno de Souza e Silva & Ney Passos—Petrobras Engineering.
4. Pipeline Integrity Program, Paulo de Tarso Arruda Correia—Petrobras Transport.
5. Improving pipeline performance The PRODUT program helps Petrobras improve operational reliability, increase capacity, and maintain environmental safety. By Ney Passos, Petrobras Brasil S.A., Rio de Janeiro, Brazil.
6. RP 1113 Developing a Pipeline Supervisory Control Centre September 2007.
7. Transpetro's gas pipeline network, By Marcelo Renno, Natural Gas Director of Transpetro.
8. API RP 5UE Recommended Practice for Ultrasonic Evaluation of Pipe Imperfections.

9. Improving pipeline performance, PRODUT.
10. Pipeline Integrity Program, Paulo de Tarso Arruda Correia—Petrobras Transport.
11. Joe Evangelista (Winter 2002). "Scaling the Tanker Market". Surveyor (American Bureau of Shipping).
12. UNCTAD 2006 Price for new vessel in 2005 in US \$ Millions.
13. UNCTAD 2006 Five year old ship in 2005 in US \$ Millions.
14. Comparison of Spherical and Membrane Large LNG Carriers in Terms of Cargo Handling, Kiho Moon et al Hyundai Heavy Industries, Gastech Bilbao 2005.

Chapter 11—Refining

1. See BP Statistical Review 2008 page 18.
2. Thermodynamic Properties and Characterization of Petroleum Fractions, February 1988 API Monograph Series. Each publication discusses the properties of solid, liquid, and gaseous phases of one or a few closely related, industrially important compounds in a compact, convenient, and systematic form. In addition to the basic physical properties, each publication covers density, molar volume, vapour pressure, enthalpy of vaporization, surface tension, thermodynamic properties, viscosity, thermal conductivity, references to properties of mixtures, and spectrographic data.
3. Idem.
4. Wade, L.G. (Sixth Ed., 2006). Organic Chemistry. Pearson Prentice Hall. pp. 279.
5. For HSE effects see Report of the Peer Consultation Meeting on n-Alkanes (decane, undecane, dodecane) Submission by American Chemistry Council n-Alkane VCCEP Consortium.
6. For names see Moss, G. P.; Smith, P. A. S. (1995). "Glossary of Class Names of Organic Compounds and Reactive Intermediates Based on Structure (IUPAC Recommendations 1995)". Pure and Applied Chemistry 67: 1307–1375.
7. Organic Chemistry by Wade, L.G. (Sixth Ed., 2006). Pearson Prentice Hall.
8. Handbook of Fluidization and Fluid Particle Systems by Wen-Ching Yang (2003). ISBN 0-8247-0259-X.
9. Octane-enhancing Zeolitic FCC Catalysts: Scientific and Technical Aspects by Julius Scherzer (1990). ISBN 0-8247-8399-9.
10. FCC Catalysts for Improved Refinery Profitability (1997 Annual National Petrochemical and Refiners Association [NPRA] Meeting).
11. TTNRG Natures Best Issue 10 www.ttnrg.com
12. Pioneer of Catalytic Cracking: Almer McAfee at Gulf Oil (North American Catalysis Society website)

13. Commonly reported in the technical press.
14. TTNRG Nature's Best Issue 10 www.ttnrg.com.
15. No one seems to be in a hurry to add refining capacity.
16. This is purely illustrative as it assumes full recovery rate, no consideration of lifting costs. Different assumptions would yield different final estimates. For example, assumptions based on worldwide oil scarcity would drive the number up, while assumptions based on rapid conversion to sustainable energy sources would drive the number down. World Energy Outlook 2008, published by the International Energy Agency.

Chapter 12—Paper Barrels—Oil and Gas Markets

1. The cycle can be self-fulfilling and examples are the 'contango' situation in oil futures where spot prices are lower than long term futures or backwardation where spot prices are higher than futures.
2. The difference between imports and exports can make a huge difference to profits.
3. This is a guideline pricing differential for illustration only.
4. Planned maintenance is a growing problem as the refinery stock ages.
5. With increased volumes of heavy and sour oil blending and purchasing is already becoming a complex trading task.
6. The New York Mercantile Exchange handles billions of dollars worth of energy products, metals, and other commodities being bought and sold on the trading floor and the overnight electronic trading computer systems. The prices quoted for transactions on the exchange are the basis for prices that people pay for various commodities throughout the world.
7. The Chicago Mercantile Exchange was formed in 1919. Initially, its members traded futures contracts on agricultural commodities via open outcry. This system of trading—which is still in use today—essentially involves hundreds of auctions going on at the same time albeit with today's electronic option available too.
8. ICE conducts its energy futures markets through ICE Futures Europe, its U.K. regulated London-based subsidiary, which offers the world's leading oil benchmarks and trades nearly half of the world's global crude futures in its markets.
9. The oil and gas markets are simply too large for any single group to control prices.
10. There would be too many variables between OPEC and non-OPEC producers let alone considering consumer countries.
11. TTNRG Nature's Best.
12. This would hurt producers equally with the loss in revenues.
13. The Titanic sank for good; oil and gas markets go up and down

14. Harts E & P Sept 2002 Drilling Column. 'Manage your tapped resources'. Discussion on industry cycles.
15. Idem.
16. Despite economic uncertainty certain deepwater projects are still going ahead.
17. See Yergins Prize 'Sweating'.
18. The Big Crew Change.
19. See 2005 US Senate Inquiries into Oil Prices.
20. Global economic growth has slowed down during the current recession but it will not disappear.
21. The comfort lifestyle.
22. See IMF commodity price charts.
23. This is the basis for substituting oil.

Chapter 13—Renewable Energy

1. The 2001 joint statement was signed by the scientific academies of Australia, Belgium, Brazil, Canada, the Caribbean, China, France, Germany, India, Indonesia, Ireland, Italy, Malaysia, New Zealand, Sweden, and the UK. The 2005 statement added Japan, Russia, and the U.S. The 2007 statement added Mexico and South Africa. Professional societies include American Meteorological Society, American Geophysical Union, American Institute of Physics, American Astronomical Society, American Association for the Advancement of Science, Stratigraphy Commission of the Geological Society of London, Geological Society of America, American Chemical Society, and Engineers Australia.
2. "The Science Of Climate Change". Royal Society. May 2001.
3. Caldeira, Ken; Wickett, Michael E. (2005). "Ocean model predictions of chemistry changes from carbon dioxide emissions to the atmosphere and ocean" (PDF). *Journal of Geophysical Research* 110 (C9): C09S04.1–C09S04.12. doi:10.1029/2004JC002671. http://www.ipsl.jussieu.fr/~jomce/acidification/paper/Caldeira_Wickett_2005_JGR.pdf. Retrieved on 27 July 2007.
4. "New Study Shows Climate Change Largely Irreversible". National Oceanic and Atmospheric Administration. 26 January 2009. http://www.noaanews.noaa.gov/stories2009/20090126_climate.html. Retrieved on 03 February 2009.
5. "Eight glacial cycles from an Antarctic ice core". *Nature* 429 (6992).
6. Oerlemans, J. (2005-04-29). "Extracting a Climate Signal from 169 Glacier Records.
7. The Scott Polar Research Institute was founded in 1920, in Cambridge, as a memorial to Captain Robert Falcon Scott, RN, and his four companions, who died returning from the South Pole in 1912.

When Scott's last words, "For God's sake look after our people" were made known to the British nation, the response was tremendous. Scott himself had emphasised the importance of science and from this plea, the Institute was born.

8. Stonehouse, B., 1990. *North Pole, South Pole: a guide to the ecology and resources of the Arctic and Antarctic*. London, Prion, 216 pp.

9. The U.S. Integrated Ocean Observing System (IOOS) is the U.S. contribution to the Global Ocean Observing System, or "GOOS." GOOS is a global system for sustained ocean observations designed to improve weather forecasts and climate predictions.

10. The moored buoys are deployed in the coastal and offshore waters from the western Atlantic to the Pacific Ocean around Hawaii, and from the Bering Sea to the South Pacific. The moored buoys measure and transmit barometric pressure; wind direction, speed, and gust; air and sea temperature; and wave energy spectra from which significant wave height, dominant wave period, and average wave period are derived.

11. Eilperin, Juliet (2005-07-02). "Climate Plan Splits U.S. and Europe". *Washington Post*. <http://www.washingtonpost.com/wp-dyn/content/article/2005/07/01/AR2005070101915.html>. Retrieved on 5 November 2006.

12. Hoyt, Douglas V.; Kenneth H. Schatten (1993–11). "A discussion of plausible solar irradiance variations, 1700–1992". *Journal of Geophysical Research* 98.

13. See Al Gore *An Inconvenient Truth*.

14. An interesting take on this is 'Biomass with capture: negative emissions within social and environmental constraints' by James S. Rhodes and David W. Keith.

15. Namely Shell, BP and Exxon Mobil.

16. *The Global Liquefied Natural Gas Market: Status and Outlook* Energy Information Administration, US EIA.

17. Society of International Gas Terminal and Tanker Operators *World LNG Industry Standards*.

18. US EIA *LNG Energy Brief* 2008.

19. *Idem*.

20. *Idem*.

21. *BP Statistical Review 2008* (Source Cedigaz).

22. *Idem*.

23. *Idem*.

24. *Idem*.

25. *Idem*.

26. *Idem*.

27. "Fuels of the Future for Cars and Trucks", Dr. James J. Eberhardt, Energy Efficiency and Renewable Energy, U.S. Department of Energy, 2002 Diesel Engine Emissions, Reduction (DEER) Workshop, San Diego, California, August 25 - 29, 2002.

28. LPG offerings can be widely seen in these countries.

29. To enhance energy independence in the face of apartheid-related embargoes, South Africa satisfied most of its diesel demand with natural gas and coal derived diesel for decades and is still using the fuel in significant quantities. More recently, global concerns about energy supplies and costs and the environment have created interest in converting fuels to liquids elsewhere. For example, Shell markets diesel as a premium diesel blend in Europe and Thailand. See Shell booklet What is GTL?

30. Unconventional Gas Production: Hydrated Gas By James Mansingh and Jeffrey Melland. Hydrated gas reserves are currently estimated between 100,000 and 270,000,000 trillion standard cubic feet (TCF).

31. US EIA Office of Civilian Radioactive Waste Management.

32. US EIA data shows the World's nuclear industry having a total of 443 commercial nuclear generating units with a total capacity of about 364.9 gigawatts.

33. See EIA carbon emission.

34. It is common for hydro-electric plants to have their operational lives extended.

35. There is also the consideration of deforestation in building the hydro-electric plant.

36. Bolton, James (1977). Solar Power and Fuels. Academic Press, Inc.. ISBN 0121123502.

37. Balcomb, J. Douglas (1992). Passive Solar Buildings. Massachusetts Institute of Technology. ISBN 0262023415.

38. See Shell Booklet on Solar Power and CIS.

39. Hydrogen is commonly used during the electrochemical reaction. This raises a separate issue as to whether the hydrogen is chemically generated or reformulated from natural gas or methanol.

40. Sourced from Linha 10 renewable energy consultancy.

41. Despite this ethanol is increasing market share.

42. The fuel standard is higher and can be 99% reached by denaturing.

43. Ethanol produced by steam cracking is similar to Hydrogen derived from fossil fuels it is not a sustainable stream.

44. This is likely to increase in the future as ethanol becomes more commonly used.

45. This has not occurred in Brazil which has ample arable land.

46. Biomass Cogeneration As an aside, it is worth noting that electrical energy prices are country-specific; KWH is priced at 11.35 US cents in Bolivia compared to 5 US cents in Canada (Manitoba). Predicted oven dryer and engine performance is estimated at 62% and 38.6% respectively. These figures are based on past performance and take into consideration both scheduled maintenance and non-scheduled downtime.

47. Linha 10 database.

Chapter 14—Exits From the Hydrocarbon Highway

1. These are:

- a) Power Generation [PGOil +PGGasTurbine (Non Ethanol/Brighton cycle) +PGGasSteam (Combustion)] (Gasoil/Fueloil) Gas & Oil (Methane, Heavy Oil)
- b) Heating [H Industrial Process + H Construction +H Domestic Premises +H Commercial Premises] (Gas, Kerosene, Gasoil)
- c) Transport [T Light Automotive Cars + T Aviation + T Marine Light T Marine T Military T Industrial + T Heavy Automotive Truck/Construction/Mining T Heavy Automotive Bus +T Train] (Gasoline, Diesel, Heavy Oil)
- d) Petrochemicals [D Alkane Feedstocks (Naphthas) + D Arene Feedstocks (Pharmaceuticals) + D Alkene Feedstocks Plastics + D Foods + Resins & Waxes]
- e) Lubricants [L GearOil + L IndustrialGrease], and
- f) Surfacing [S Road+S Roof] Roofs, Cement.

2. Especially considering man-made Gas.

3. That make up the Oil and Gas Demand Equation: [PGGT+PGGS+PGO]+[HIP++HCon+HDP+HCP]+[TLAC+ TA + T M+ THAT+THAB+TT]+ [PCArF (Pharmaceuticals) + PC AlF PC AlkeneF + PC RW] + [LGO + LIG] + [SRd+SRf] 2007 World Demand (Consumption) Gas 2921.9 BCM and Oil 85.22 million bopd 2007 World Supply (Production) Gas: 2940 BCM and Oil 81.53 million.

Supply = [PGMethaneGT +PG MethaneGS+LPG,LNGGS + PG Oil] + [HGasOilIP+HGasDP Diesel, CNG,LPG] +[TLAC Gasoline+ Diesel + TA Compressed Natural Gas, Liquid Petroleum Gas + TM Diesel+ THAT Diesel+THAB Diesel+TT Heavy Oil] + [PCArF Naphtha (Pharmaceuticals) + PC AlF Naphtha PC AlkeneFNaphtha + PC RW Heavy Oil] +[LGOHeavy Oil + LIGHeavy Oil] + [SRdAsphalt+SRfBitumen].

4. This is our goal.

5. See EIA IEO 2008 Outlook.

6. See EIA IEO 2008 Outlook.

7. Idem.

8. Idem.

9. Certainly the EIA IEO 2008 Outlook thinks so.
10. EIA.
11. EIA.
12. EIA.
13. Idem.
14. Idem.
15. EIA.
16. EIA Footnote.
17. Increasing Feedstock Production for Biofuels: Economic Drivers, Environmental Implications, and the Role of Research. See also Options for Alternative Fuels and Advanced Vehicles in Greensburg, Kansas Harrow, G.
18. Further is the intrinsic volatility of the oil markets which complicates investment in renewables.
19. Exchange with EIA.
20. Exchange with EIA.
21. Brazil is a case in point hence why it was chosen.
22. BP Statistical Review 2008.
23. Idem.
24. Idem.
25. Gasoline and Ethanol Prices Fall” (in Portuguese). Folha Online 18 09 2008.
26. US DOE Flexible Fuel Vehicles: Providing a Renewable Fuel Choice. Again no single source of energy is universally applicable.
27. See also The Methanol Story: A Sustainable Fuel for the Future Roberta J Nichols.
28. US DOE Flexible Fuel Vehicles: Providing a Renewable Fuel Choice.
29. In many ways this is more elastic than transportation demand.
30. It is the backdrop of high oil prices that makes renewables viable.
31. The trends for continued economic and population growth will create further demand on oil and gas in the medium and long term.
32. The problem is that not even the world’s foremost thinkers can satisfactorily predict the cycles.
33. Due to the vicious cycle involved it is likely that change will be slow and steady.

About the Author



Wajid Rasheed, SPE, MCIOJ, MIOD, is the author of *Hydrocarbon Highway: A Crash Course in Oil, Gas and Energy*. He is also Chief Executive Officer of EPRasheed UK, publishers of *Saudi Arabia Oil and Gas* and *Brazil Oil and Gas* and is a board member of *Petroleum Production UK*. He has worked for more than a decade in the oil industry, with operational and managerial postings in Dhahran, Dubai, Rio de Janeiro, and Caracas. He also has worked in corporate R&D commercialization in Houston and Aberdeen for various service companies and as a technical consultant for oil companies. Rasheed is the author of more than 200 published articles and seven SPE papers. He is currently serving as chairperson of the 2009 SPE LACPEC Young Professionals Workshop and also serves on SPE MEOS 2009 Committee. He has several oilfield patents pending.

"There have been many books concerning the oil industry. Most are technical, some historical (e.g. the Prize) and some about the money side. There are few, if any, about the oil industry that the non-technical person will appreciate and gain real insight from. Wajid Rasheed in this book, *The Hydrocarbon Highway*, has made a lovely pen sketch of the oil industry. The book begins with the geology of oil and gas formation and continues with the technical aspects of E & P, distribution, refining and marketing which are written in clear language. In particular, the process of oil recovery is outlined simply and with useful examples. There is a short history of how the oil companies have got to where they are, and finally a discussion concerning the exits—alternative energy. This is all neatly bundled into 14 chapters with many beautiful photographs and a helpful glossary. The book is intended to give an overture to the industry without bogging the reader down. I enjoyed the journey along the highway."

Professor Richard Dawe of the University of West Indies, Trinidad and Tobago

"A crash course in Oil and Energy. *The Hydrocarbon Highway* is a much-needed resource, outlining the real energy challenges we face and potential solutions."

*Steven A. Holditch, SPE, Department Head of Petroleum Engineering,
Texas A&M University*

"I found the book excellent because it provides a balanced and realistic view of the oil industry and oil as an important source of energy for the world. It also provides accurate information which is required by the industry and the wider public. Recently, I read several books about oil which portrayed it as a quickly vanishing energy source. It seems that many existing books predict a doomsday scenario for the world as a result of the misperceived energy shortage, which I believe is greatly exaggerated and somewhat sensational. Therefore the book bridges the existing gap of accurate information about oil as a necessary source of energy for the foreseeable future. The *Hydrocarbon Highway* should also help inform public opinion about the oil industry and our energy future. It looks at the oil industry in an up-to-date and integrated view and considers the most important factors affecting it."

*Dr AbdulAziz Al Majed, the Director of the Centre for Petroleum and Minerals
at the Research Institute at King Fahd University of Petroleum and Minerals*

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