OIL AND NATURAL GAS

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Summary

During the last 100 years the oil and gas industry has developed from being a minor industry to being one of the major industries, influencing national economies by the demand for and price of petroleum products. Petroleum is a non-renewable resource transformed from organic materials originating from ancient plants and animals. Transformation into petroleum products is due to the pressure and heat present in rock formations buried at several km depth.

Geological information, supplied by traditional and new technology that allows the surveyor to “see” into the ground, provides petroleum exploration companies with a fair chance of finding gas and other petroleum resources when they drill exploration wells. When the drilling is successful, crude oil or gas or a combination of both can be brought to the surface. Crude oil is processed and transported to a refinery for the production of end products. Gas is processed to remove impurities before being transmitted through large pipelines to the market.

The potentially recoverable world resource base of conventional crude oil and natural gas is estimated as being about 272 gigatonnes of oil and 255 gigatonnes of oil equivalent of gas. Natural gas hydrates, as well as unconventional resources such as extra heavy oils, tar sands, gas in tight sands, and coal bed methane, are not included in these estimates but must, none the less, be recognized as being present in very large quantities. It is not known how, if, or when, the unconventional resources or hydrates will become major components of world energy consumption, but their development must be followed carefully for signs of economic life or political/economic preference.

The oil industry has realized that environmental challenges are here to stay, and must be taken seriously if the companies are to retain their social legitimacy. In the 1990s they have taken major steps to integrate environmental issues in their overall business concept. The oil industry has shown that environmental challenges are manageable. On climate change, however, the industry is ambivalent and its responses diverge. At present it therefore seems impossible to say whether this challenge is another environmental problem that the industry will learn to handle, or whether it means the beginning of a new energy revolution.

The world gas trade is being integrated, and nations are steadily opening their economies to competition and deregulation. A truly international gas market can be envisaged in the foreseeable future, driven by the same forces that have spurred globalization.

New technologies such as fuel cells, distributed generation networks, hydrogen storage systems, gas-to-liquid technology, and microgenerators could radically change the world’s energy systems. An economy based on hydrogen as the “ultimate” fuel will probably develop during the first half of the twenty-first century. The global promotion of an open gas market and new technological developments may achieve significant reductions in carbon emissions in the years ahead.

1. Introduction

The impact of the oil industry on the economies of many countries is so dominant that an understanding of the underlying principles of its activities has become of much wider interest. Governments, academia, the news media, and technical personnel outside of the industry, are now much more interested in learning about oil and natural gas activities than in the past. Accordingly, the scope of this theme is technically oriented to provide an outline of the processes of today's petroleum industry—from assessing the resource base through exploration and production of hydrocarbons to products—as well as the marketing and use of its products. Some historical background and explanation of the economic context in which the oil, gas, and petrochemical business operates have been included, as well as how the oil industry responds to environmental aspects and contributes to sustainable development.

2. History and Fundamentals of Oil and Natural Gas

Small surface occurrences of oil and gas are known all over the world. These may represent escapes of natural gas, seepages of liquid oils, deposits of semi-solid bitumens, or veins of asphalt impregnating porous rocks. In the ancient world, the early civilizations of Mesopotamia used local asphalt obtained from hand-dug pits as building cement, for ornamental purposes, and for caulking boats. Liquid oil was first used as a medical drug by the ancient Egyptians, Persians, tenth century Sumatrans and pre-Colombian Indians. In North America, the Senecas and Iroquois and the Indians of Venezuela used crude oil for ceremonial fires and body paint. It was also used as a fuel in China, being produced about A.D. 200 from shallow, percussion-drilled wells. Natural gas was similarly produced and transported through pipelines from hollowed-out bamboos. Oil products were also highly valued as weapons of war.

With the Renaissance, a number of shallow sources of crude oil and asphalt were discovered in countries outside Europe and samples were brought back by travelers. Paraffin wax was first obtained on a commercial basis from shale oil at about the same time, and was subsequently extensively used in the manufacture of candles. As in the Middle East, asphalt was used in Europe for the caulking of boats and the lining of hand-woven baskets, while liquid oil was collected from surface seepages for medical purposes and illumination. Although the Chinese had devised a method for drilling shallow wells much earlier, their techniques had not been copied elsewhere, and until 1859 oil was still generally obtained from seepages or shallow hand-dug pits. In August of that year, however, the first modern oil-well was percussion-drilled to a depth of 69 feet by Edwin Drake in Pennsylvania, inaugurating the modern oil industry.

Until the turn of the century, petroleum was valued chiefly for its yield of illuminating kerosene, with gasoline being burned off and the heavier parts of crude oil discarded. By 1920, however, crude oil as an energy source came into its own as a source for oil-fired electricity generating plants and gasoline for internal combustion engines. Outside the United States, the huge individual outputs of a relatively small number of Baku wells produced a substantial part of the world oil production, a position maintained by the USSR and now by the Russian Federation together with the other Former Soviet Union states. In the 1920s Mexico, and subsequently Venezuela, occupied the position of the world's second largest producer. Venezuela was for many years after 1930 the world's second largest crude oil producer and the foremost oil exporting state. Several countries whose oil fields were developed early in the history of the industry still continue to be substantial producers. However, at the end of the twentieth century their outputs are small compared with those of the oil producing states of the Middle East, which contain the major part of the world's identified crude oil reserves. The Middle East has shown the most rapid and impressive increase of petroleum production since the Second World War and has become the chief supplier of Western Europe and much of the Eastern Hemisphere.

The post-war years have also seen the rapid emergence of the continent of Africa as an important oil producing region. In North Africa, large new accumulations of oil and gas have been discovered and developed in Algeria, Libya, and Egypt. In addition to these countries, Somalia, Sudan, and Tunisia hold a large potential for oil resources. Angola in the south is one of the countries with a large potential for increase in production. At the turn of the twentieth century Nigeria was the largest oil producing country in Africa.

	Oil		**Natural gas**	
	Production	**Reserves**	**Production**	**Reserves**
America				
Mexico	0.166	4.1	0.034	0.765
USA	0.355	3.5	0.486	4.185
Venezuela	0.161	10.5	0.029	3.636
Europe				
Norway	0.149	1.4	0.046	1.053
Former Soviet Union				
Russian federation	0.305	6.7	0.496	43.322
Middle East				
Iran	0.175	12.3	0.047	20.698
Iraq	0.126	15.1	—	2.799
Kuwait	0.099	13.3	0.006	1.341
Saudi Arabia	0.412	36.0	0.042	5.210
United Arab Emirates	0.111	12.6	0.034	5.399
Africa				
Libya	0.068	3.9	0.005	1.179
Nigeria	0.100	2.2	0.005	3.159
Asia				
India	0.036	2.3	0.022	0.585

Table 1. 1999 Annual production and reserves of selected countries, in gigatonnes of oil equivalent. Source: BP Amoco Statistical Review of World Energy 2000

The most important developments in Europe have been the emergence of the Norwegian and British continental shelves as major oil and gas producing regions. Although China has produced small volumes of petroleum for many centuries, it is only relative recently that modern exploration techniques have been applied to the most promising of its huge sedimentary regions. As a result of these efforts, China was seventh among world oil producing countries in 1999, and the exploration of its many onshore and offshore basins over the next few years is likely to result in a notably higher level of oil production in the future. By 1960 the USSR had successfully developed its own production, most of which was consumed inside the Soviet block, with the remainder being exported to other communist countries. The world's gas production nearly doubled over the last quarter of the twentieth century, and the Russian federation became the world's largest exporter of gas. The petroleum industry in the twenty-first century operates in a market that has become highly politicized and is of international, economic, social, and environmental significance. Efficient supplies in the years ahead will be dependent upon the degree to which the objectives and priorities of national and international authorities are reconciled with the needs of commercial operators and environmental requirements.

2.1. Chemistry of Organic Matter Precursor to Hydrocarbon

There has been considerable debate over the origin of petroleum. Today, most scientists believe that petroleum products and natural gas come from the remains of ancient plants and animals. Erosion processes carried these organic remains down rivers and streams onto shorelines where they were deposited along with mud and silt. Over time, they were covered by increasing amounts of sediments, and subsequently subjected to a lengthy and relatively gentle heating process as a result of burial and increasing sedimentary overburden. After heating, the transformed organic matter consists of a mixture of complex organic compounds. A small part can be extracted by organic solvents and is called bitumen. The rest is not extractable in organic solvents and is called kerogen. Kerogen is the most important part because it can be converted to petroleum by thermal alteration. The structure of kerogen is varied and complex. Chemical analysis has shown that it normally consists of around 80 percent carbon, 6 to 10 percent hydrogen, 5 to 8 percent of oxygen, and up to 5 percent sulfur and 2 percent nitrogen. Three main types of kerogen can be distinguished microscopically and chemically. The three types are related to different types of organic matter and different types of depositional conditions.

Kerogens described as Type I are derived from micro-organisms living in aquatic environments consisting of mainly algal and amorphous kerogen and is highly likely to generate oil; Type II kerogens are derived from mixed terrestrial and marine source material that can generate waxy oil; and Type III kerogens come from woody terrestrial source material that typically generates gas.

2.2. Hydrocarbon Generation

Hydrocarbon generation starts during diagenesis. Diagenesis, the initial stage of kerogen alteration, is thought to begin during the deposition of the first few tens or hundreds of meters of sediments. After deposition, sediments are compacted as they are buried beneath successive layers of sediment and cemented by minerals that precipitate from solution. Under the influence of bacteria and relatively small increases of temperature and pressure, progressive changes in the makeup of the kerogen occur. The second stage of transformation, termed catagenesis, is believed to begin when a minimum temperature of about 60 °C has been attained, that is, when the thickness of sedimentary overburden has reached several kilometers.

Catagenesis involves the thermal splitting of various chemical bonds in the kerogen, with a resultant release of smaller hydrocarbon molecules made up of hydrogen and carbon atoms. The number of carbon atoms determines the oil’s relative “weight” or density. Gases typically have one to four carbon atoms, while heavy oils and waxes may have fifty, and asphalts, hundreds. Beyond the depth at which the 150 °C temperature level occurs, the zone of metagenesis begins, with increasing proportions of “dry gas” components being formed and the remaining organic matter eventually decomposing into graphitic carbon and methane. The geological history is the most important factor in determining the characteristics of the generated hydrocarbon.

The existence of ultra deep gas reservoirs at depths of 7,000–13,000 m suggests the existence of stable methane but their reservoir and geologic characteristics are not well understood. Processes involving H_2, CO, and CO_2 in subduction areas and rift zones as well as the mantle combining under the 300 to 500 ºC temperature range could form hydrocarbons, with ferrous iron as a helper in the reduction reactions. This possibility is substantiated by recent laboratory results where methane is produced from bicarbonate ions and hydrogen at temperatures up to 400 ºC using an iron–nickel alloy found in certain parts of the oceanic crust. Although the general evidence for an organic origin of oil makes non-organic theories of large-scale origin difficult to accept, a “duplex” origin certainly seems possible.

2.3. Hydrocarbon Migration

Once formed, fluid hydrocarbons must be expelled (primary migration) from the capillary pores of the fine grained organic rich source rocks. A reduction in porosity caused by gravitational compaction through continuing subsidence and loading (sedimentation) tends to expel the pore waters and their dissolved or emulsified hydrocarbons from the finer grained, less permeable source rocks into coarser grained and more permeable (and porous) carrier and reservoir beds (secondary migration) before entrapment and accumulation can occur.

Primary migration proceeds at least as long as gravitational compaction continues to reduce source rock porosity and diagenetic alteration of clays continues to release unbound water for expulsion. Primary migration merges into secondary migration, in which hydrocarbons begin to move more freely through coarser grained carrier beds (or fractures) having the physical characteristics of reservoir rocks. If permeable avenues exist to permit the expressed fluids to move upwards, the hydrocarbons escape more or less directly to the surface. Light oils eventually evaporate also. However, in most cases, the petroleum products never make it as far as the surface.

2.4. Hydrocarbon Entrapment

Petroleum or natural gas constituents that migrate gravitationally “up-dip” along natural escape routes through permeable layers are diverted toward the locus of minimum fluid pressure where they tend to be trapped. Entrapment of fluid hydrocarbons occurs wherever their tendency to escape to the atmosphere is interrupted or significantly impeded by any impervious or relatively impermeable barrier (cap rock) having a geometry suitable to hydrocarbon aggregation and accumulation, rather than to diversion. There are two main categories of gas and oil traps: structural and stratigraphic traps. Structural traps are caused by the folding or deformation of layers of rock. Two common varieties of structural traps are anticlines and faults. An anticline trap is an upward, arch-like folding in the rock layers. The second common variety of structural traps, fault traps, form when faults displace the rock layers, and the layers containing natural gas and oil are enclosed by cap rocks that are adjacent to them. The stratigraphic category of traps is characterized by a change in the reservoir layer itself leading to the entrapment of gas and oil. This may occur when a layer of sediment with large pores that allow the petroleum to move through it, gradually forms an impermeable layer of rock where the grains of the sediments are tightly compacted and become smaller. Any region of porous and permeable rock is a potential “trap” if it is connected more or less directly with pathways along which hydrocarbon fluids migrate (or once migrated), and is enveloped or sealed by a barrier that prohibits hydrocarbon escape. A myriad different kinds of “traps” have been recognized, and no attempt is made here to describe more varieties.

As the gas and oil move upwards through the permeable layers of rock, they displace water that was also trapped in pores of the sedimentary formations. When oil and gas reach the trap and cease upward movement, they separate from one another according to their varying densities. Not all of the water is separated from the petroleum however, and between 10 percent and 50 percent of the oil and gas accumulation contains salt water, which must be removed before the gas or oil can be used.

When a petroleum or natural gas accumulation is opened by drilling, the volatile hydrocarbon contents are able to resume their journey to the atmosphere. There they are oxidized, one way or another, to carbon dioxide and water, thereby bringing to completion the cycle that began—in some instances hundreds of millions of years earlier—with photosynthetic fixation of carbon in the organic compounds of living plants.

The ultimate fate of most hydrocarbon accumulations that are not opened by drilling is to leak their contents to the surface very slowly (hence the historical importance to petroleum exploration of surface seepages, and the continuing efforts to understand surface geochemical anomalies and to develop practical geochemical prospecting methods). Accumulations that are opened by erosion at the surface following tectonic uplift oxidize gradually through the actions of oxygenated waters circulating from the surface, or are degraded by bacterial decay. Doubtless the relative scarcity of geologically ancient petroleum is partly due to its volatile nature in relation to the abundant opportunities for escape through geologic time.

3. Exploration for Oil and Natural Gas

When people first began to search for hydrocarbons, the only known method was to look for surface oil seeps in the ground. Of course, in the early days, people had little idea of what the hydrocarbons were, much less how or why they formed where they did. Today, geologists have given the industry much more information about petroleum accumulations and their history. This information, along with new technology that allows the surveyor to "see" into the ground, provides hydrocarbon exploration companies with a much better probability of finding petroleum resources when they drill an exploration well. Successful exploration depends on the ability to predict the presence of oil accumulations with accuracy. Historically the success rate was one discovery for every ten wells drilled, but has improved to a rate of about one in three or four in the present day. As explained in Section 2, the accumulation of oil or gas can be considered as the product of a whole series of independent chance events that resulted in the existence of a source rock with adequate organic content and temperature sufficient for hydrocarbon generation, as well as reservoir and seal-rocks in the correct geometrical and time relationships to each other. The geological variations over time are so numerous that the chance is great that one or more of the critical factors will be missing and that a well outcome will be dry. Exploration is therefore a highly sophisticated activity where many specialists need to co-operate in order to increase efficiency. The petroleum business has therefore always encouraged the development of new technology, more efficient tools and processes and, most important, information flow efficiency.

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Bibliography

Adelman, M. A. 1995. *The GENIE out of the Bottle: World Oil since 1970*. Cambridge, Mass., MIT Press. [This book gives a good account of the price fluctuations and the OPEC role in price determination.]

Arnaud Gerkens, J. C. D' 1989. *Foundation of Exploration Geophysics.* Amsterdam, Elsevier. [This book presents a general overview of prospecting. as well as geophysical exploration methods.]

Barker, C. 1996. *Thermal Modeling of Petroleum Generation: Theory and Applications*. Amsterdam: Elsevier. [This book gives a good overview of the aspects related to the formation of petroleum.]

Berger, Z. 1994. *Satellite Hydrocarbon Exploration: Interpretation and Integration Techniques*. Berlin, Springer. [This book represents the experience from many case studies where remote sensing proved to be valuable for the location of exploration targets.]

Crowley, W. R. 1996. *Oil and Gas on the Internet*. Houston, Tex., Gulf Publ. Co. [This book gives a review of how to acquire oil and gas knowledge through the Internet.]

Dahlberg, E. C. 1995. *Applied Hydrodynamics in Petroleum Exploration*. New York, Springer. [This book is a classic monograph on petroleum exploration, fluid dynamics and migration of petroleum into traps.]

Doré, A. R.; Sinding-Larsen, R. (eds.) 1996 *Quantification and Prediction of Petroleum Resources.* NPF Special Publication Nr.6. Amsterdam, Elsevier. [This book represents a collection of state of the art papers regarding the estimation of the resource base.]

Durand, B. 1980. *Kerogen: Insoluble Organic Matter from Sedimentary Rocks*. Paris, Editions Technip. [This is a reference text from one of the pioneers in Organic geochemistry.]

Düppenbecker, S. J.; Iliffe, J. E. 1998. *Basin Modelling: Practice and Progress*. London, Geological Society. [This book gives a comprehensive overview of basin modelling, the accumulation of petroleum in deposits, as well as oil recovery related to reservoir properties.]

Geyer, R. A. 1992. *CRC Handbook of Geophysical Exploration at Sea*. Boca Raton, CRC Press. [This is a handbook representing a manual of offshore geophysical exploration methods.]

Gerger, B.; Anderson, K. 1992. *Modern Petroleum: A Basic Primer of the Industry*. PennWell Publishing. [This book is a good introductory text covering the petroleum industry.]

Hannesson, R. 1998. *Petroleum Economics: Issues and Strategies of Oil and Natural Gas Production*. Westport, Conn., Quorum. [This book covers the petroleum economy and provides a good coverage of taxation and petroleum prices.]

Henriet, J.-P.; Mienert, J. 1998. *Gas Hydrates: Relevance to World Margin Stability and Climate Change*. London, Geological Society. [This book addresses the geohazard aspect of gas hydrates and its relation to global change.]

Hovland, M.; Judd, A. G. 1988. *Seabed Pockmarks and Seepages.* London, Graham and Trotman. [This book is a rather unique collection of observations of gas seepage on the sea floor.]

Hyne, N. J. 1991. *Dictionary of Petroleum Exploration, Drilling and Production*. Tulsa, Okl., PennWell. [This book gives an overview of the most used terms within the petroleum industry in a popular and precise manner.]

——. 1995. *Nontechnical Guide to Petroleum Geology, Exploration, Drilling and Production*. Tulsa, Okl., PennWell. [This book may be particularly useful for non-specialists who would like to get an overview of the upstream petroleum sector.]

Julius, D-A.; Mashayekhi, A. 1990. *The Economics of Natural Gas*. Oxford University Press. [This book will ease the task of analysts and decision makers concerned with natural gas by providing a practical framework for addressing the critical economic questions.]

Lerche, I. 1997. *Geological Risk and Uncertainty in Oil Exploration*. San Diego, Academic Press. [Petroleum reserves. Forecasting statistical methods. Risk assessment.]

Levorsen, A. I. 1967. *Geology of Petroleum*. San Francisco, Freeman. [This book is old, but it is still a classic and most of it is still valid.]

MacDonald, J. 1997. *European Oil Refining: Strategies for a Competitive Future*, London, Financial Times Energy. [Describes the refinery scene in Europe.]

Makogon, Yu. F. 1997. *Hydrates of Hydrocarbons*, Tulsa, Okl., PennWell. [A good text for people who would like to get better acquainted with hydrates.]

Parasnis, D. S. 1997. *Principles of Applied Geophysics*, London, Chapman and Hall. [One of the pioneers of exploration geophysics exposes the important aspects of geophysical prospecting with many examples from the mineral industry.]

Reis, J. C. 1996. *Environmental Control in Petroleum Engineering*, Houston, Tex., Gulf. [This book covers the environmental issues related to petroleum engineering.]

Roberts, S. 1997. *The Fundamentals of the Natural Gas Industry*. London: Petroleum Economist. [A thorough and good overview of the natural gas industry.]

Rojey, A. 1997. *Natural Gas: Production, Processing, Transport*. Paris, Edition technip. [A comprehensive survey of the upstream natural gas sector.]

Selley, R. C. 1998. *Elements of Petroleum Geology*. San Diego, Academic Press. [This is a new edition of a popular book on the basic aspects of petroleum geology.]

Sloan, E. D. 1998. *Clathrate Hydrates of Natural Gas*. New York: Dekker. [A comprehensive text on the fundamentals of hydrates.]

Speight, J. G. 1998. *Petroleum Chemistry and Refining*. Washington, D.C., Taylor and Francis. [A good overview of the various processes within the geochemistry and the refining of petroleum.]

Stoneley, R. 1995. *Introduction to Petroleum Exploration for Non-geologists*. Oxford, Oxford University Press. [This is an excellent introductory book; it is self explanatory, avoiding to a large degree the use of technical terms.]

Surdam, R. C. 1997. *Seals, Traps, and the Petroleum System*. Tulsa, Okl., American Association of Petroleum Geologists. [This book is an authoritative text describing the various aspects of trapping of petroleum.]

Tedesco, S. A. 1955. *Surface Geochemistry in Petroleum Exploration.* London, Chapman & Hall. [This is one of a small number of books addressing geochemical exploration techniques as a screening tool which should be used in conjunction with other methods.]
Tussing, A. R.; Tippee, B. 1995. *The Natural Gas Industry: Evolution, Structure, and Economics.* PennWell. [This is a very well-written book, providing a good overview of the natural gas industry with chapters outlining the evolution structure and economics of natural gas.]
Tyson, R. V. 1995. *Sedimentary organic Matter Organic Facies and Palynofacies*. London, Chapman & Hall. [This is a rather specialized book about organic matter and its different forms in sediments.]
Van Dyke, K. 1997. *Fundamentals of Petroleum.* Austin, Tex., Petroleum Extension Service, Division of Continuing Education. [This is a particularly useful book covering petroleum engineering and petroleum technology in depth.]
Welte, D. H.; Horsfield, B.; Baker, D. R. 1997. *Petroleum and Basin Evolution: Insights from Petroleum Geochemistry, Geology and Basin Modeling*. Berlin: Springer. [This book is produced by one of the pioneers in basin analysis and gives an up-to-date overview of petroleum from its formation to its entrapment.]
Williams, B. 1991. *US Petroleum Strategies in the Decade of the Environment.* Tulsa, Okl., PennWell. [This book covers the petroleum industry and trade in relation to various Environmental aspects.]
Wiltshire, J. 1996. *Challenges for Oil Refining: Meeting New Fuel Specifications and Emissions Legislation*. London, Financial Times Energy Publishing. [This is a book addressing the problems posed by new environmental standards in relation to Refining, Petroleum Technology and Law.]

Biographical Sketch

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