EMIR CERIĆ

CRUDE OIL, PROCESSES AND PRODUCTS

A WORD FROM THE AUTHOR

Lack of professional literature in the field of crude oil processing inspired me to write this book. The book is primarily intended for the experts who work in petroleum industry, engineering companies that work on projects, oil industry and oil processing students, businessmen who are in various ways involved in this field, as well as the others.

This book is result of author's longtime work in oil industry, numerous contacts with the most eminent experts from the world's largest oil companies (Chevron – Texaco, Shell, BP, Exxon – Mobile, Conoco – Philips, etc.), license holders of technology processes for oil processing (UOP, Axens), largest engineering companies (Technip, ABB Lummus Global, Koch – Glitsch, Fluor Daniel, Foster Wheeler, Lurghi, SK Engineering, etc.), as the biggest catalyst producers (Akzo Nobel, Criterion, Haldor Topsoe, etc.), author's visits to numerous refineries in Europe, North America, Asia, and Australia, as well as result of author's passive and active involvement in various congresses and symposiums worldwide.

It is my hope that this book will contribute to better and easier understanding of subject matter, enable professionals in oil industry to review and improve their knowledge, be useful source of information for teachers who give lectures of the topics of oil processing, as well expend knowledge of students at colleges and universities and ease their entrance in the world of "black gold".

Author's effort to justify such a broad goal of the book can be a cause for slight failures, thus the comments from respectable readers will help with the improvement of the next book's edition.

I express my gratitude to prof. dr. Igor Dekanić, dr. Stevo Kolundžić and dr. Željko Vrbanović for their review, given effort, and valuable suggestions that improved this book, as well as Petrolinvest Company – Sarajevo, that made possible this book to be published.

I especially express my gratitude to Nataša Vujisić-Dardagan for English translation of this book and Jasmina Pašalić for English translation emendation. The Special thanks to my friend Mirsad Kreso their efforts and encouragement during the writing of the book and the company Petrolinvest from Sarajevo headed by Mr.Čerimagić Mustafa, who made the publication of this book. Special gratitude to my wife Nada and son Igor for their encouragement, support, patience, and understanding during book's writing.

This book I dedicate to my grandson Roko!

Dr. sc. Emir Cerić

PREFACE

In the year 1882, when the building of oil refinery in Rijeka Croatia began, one of the oldest in the world, heavy black mud that we call crude oil today did not have any market value, except as fuel for illumination (kerosene) and candle production (paraffin). This fuel, at that time known as „stone oil", was produced in the regions Pennsylvania (USA), Baku (Azerbaijan), and Galicia (Ukraine). With the invention of internal combustion engines (Otto, Diesel) and their use in road vehicles (Gottlieb Daimler) and ships, crude oil industrialization began as well as struggle to control its sources which led to numerous wars with some of them being fought even today. We can say that in 20th century this structure was established, in which link between oil, money, and power has changed the world. Soon, the crude oil has become the vital organ of the world economy, greatly affecting today's civilization. Principle „who has the oil, has the power too" has proven itself on numerous occasions in the history. Many wars in the past and present were fought because of crude oil. The structural problem in the beginning of the 21st century lies in the fact that the position of the richest crude oil sources does not coincide with the largest centers of consumption of crude oil products. Referring to proved reserves of „black gold", that is with a good reason largely accepted synonym for crude oil, sixty five percent of crude oil reserves are located in the The Middle East (Saudi Arabia, Iraq, Kuwait), so it is expected that this region in the future will be target of the most developed countries of the world, primarily USA and Great Britain, which are fighting for domination in this region of the world with the aim of securing stable oil supplies.

The price of crude oil, its production and consumption, directly affect national and world economies. It represents unavoidable factor in today economy and launching its increase which affect the development of human society. One fact is clear and without doubt, the crude oil has changed people's lives and reflection in the 20th century.

In the beginning of the 21st century when production, demand as well as the prices have reached their peaks alternative sources of energy as the substitute for crude oil started to be considered, since the anxiety started to increase that the oil would disappear . According to the proved crude oil reserves, crude oil is available for approximately another 50 years, unless new sources are discovered. Nevertheless, there are many unexplored sites of oil in the deep seas which will extend the period of availability of oil and its derivatives. According

to this, the oil will continue to be the main source of energy in the 21st century.

This book is trying to introduce its reader into secrets of crude oil processing and production of petroleum derivatives, the shortage of which would suspend normal life on earth.

This book consists of eight chapters.

The introduction covers theories of oil origins, industrialization of crude oil from the beginning of industrial exploitation and its use, oil exploration, pumping and transport, consumption, production, reserves, prices, and crude oil quality in the world. It also covers the oil markets, balances, and quality of petroleum derivatives, as well as environmental protection.

In the chapter "Refinery" there is the list of the most important factors that affect the development of the refineries. Types of refineries are also described.

The third chapter covers factors of refinery complexities.

The chapter "Chemistry of crude oil" covers chemical compounds found in crude oil, as well as chemical reactions that result from crude oil processing.

In the fifth chapter, physical properties of crude oil are described.

In the sixth chapter "Processes in petroleum refining" processes of physical separation and chemical conversion are shown.

In the seventh chapter "Refinery processes for fuel production" in details are described processes of fuel production (fuel gas, LPG, gasoline, jet fuel, diesel fuel, heating oil, as well as bitumen).

In the eight chapter "Lubricants", properties of base oils, base oils production processes, motor and industrial oils are covered.

Confident that this book will be read not only by professionals and employees in this field, but by other readers, glossary and reference list are included as well.

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1

INTRODUCTION

For a long time people were familiar with crude oil and had used it for various purposes: as fossil fuel (6000 years BC Sumerians); substance for sealing ships (Phoenicians), for plaster and coating production (Babylonians); for moisture protection and corpse mummification (Egyptians), road constructions (Persians), for lighting as well as disinfection (fumigation) agent in medicine (Chinese, Greeks, Romans); for religious purposes as cult of fire followers (Baku region) etc.

With the fall of Greek and Roman Empires use of crude oil was considerably reduced and was mostly used for medicinal purposes and ships sealing. After almost inconsiderable significance in the middle Ages, crude oil again gains its significance in the middle of XIX Century. Crude oil is brown-green-black liquid.

There are many theories about crude oil origin. However, they all can be sorted in two categories. First category includes theories which believe that crude oil has inorganic origin, and the second includes theories which believe that crude oil has organic origin. The most significant scientists who support inorganic theory are Berthelot and Mendeleev. According to their theories, which today have only historical significance, crude oil originate from ethyne (acetylene) which was created as a result of hot water and diluted acids acting on carbides. All those reactions took place inside the Earth. In presence of some substances that served as catalysts, under high temperatures and pressures ethyne bonded into multiple carbohydrates from which crude oil is consisted of.

According to organic theory, Engler is the most significant representative; crude oil originates from the remains of living organisms, i.e. plants and animals. Living organisms from which crude oil originates lived in seas and lakes. Those were algae, planktons, and the rest of tiny animal world. Those creatures, once dead, were falling on the bottom of the seas and lakes. Rivers that flowed into them brought in mud and sand which settled down on dead organisms. As the deposit thickness of the mud and send grew, pressure increased. Without air, decomposing process of dead organisms could not take place. However, due to influence of anaerobic bacteria, that organic material (carbohydrates and proteins) disintegrated into substances which by chemical reaction produce crude oil and gas. Proof that

crude oil has organic origin is its optical activity, i.e. rotation of the plane of polarization of linearly polarized light.

Crude oil and gas did not originate on the place where we find them today, but much deeper. Crude oil and gas penetrated from the depths through gaps near the surface of the Earth, and stopped in the spongy-like rocks, actually sediments (deposits), in which water was present, and above which was dense leakproof cover (marl, clay, oil shell). Crude oil and gas repressed previously present water in deposits. Gas is found in the upper layer of the deposits, crude oil in the middle layer, and water in the lower layer, which corresponds to their densities.

Passage of crude oil and gas from the point of their origin to the point of deposit is called migration. Processes which create crude oil are taking place even today.

Crude oil consists from hydrocarbons, i.e. carbon and hydrogen compounds, which under normal condition (temperature, pressure) are in gaseous, liquid, or solid state depending on complexity of their molecules. Gases are known as natural gas, liquids as crude oil, and solids as bitumen or asphalt. Most oils which are liquid contain gases and solids. Gases are separated by decreasing the pressure during production of crude oil products on oil field, as well as in primary processing of oil in refineries. Some solids such as bitumen and paraffin are produced by oil refining, while some remain in oil products. Natural gas can be found with oil or by itself. Locations of today's oil and gas deposits are in the places where seas had flooded continents long time ago (Texas, Siberia, Pannonia plain, etc.), on flooded parts of the continents along the coasts of present seas (Mexico, Venezuela, Algeria, Libya, Iran, Iraq, Kuwait, United Arab Emirates, Saudi Arabia, Nigeria, etc.), as well as under present seas (North Sea, Caspian Sea, Atlantic and Pacific Ocean).

1.1. Industrialization of crude oil

Industrial exploitation of crude oil started in 1859 in Titusville, Pennsylvania when Edwin Drake, using pipe drill, found the crude oil.

In the beginning, crude oil was distilled in retorts with a goal of obtaining kerosene for illumination, as the most important product, as well as lubricants, and bitumen. The other by-products were classified as unusable and were burned or discarded.

With the invention of internal combustion engine (Otto and Diesel) and their usage in the automotive and shipbuilding industries, and development of chemical industry at the beginning of 20th century, demand for crude oil derivatives increased resulting in the increase of oil production.

Demand for gasoline grew continually and it was difficult to satisfy it. This forced refineries to introduce process of cracking in order to increase production of gasoline.

Growth of automotive industry caused increase in road building that led to increase in production of bitumen.

Until the 1960's, USA was the largest producer of crude oil, which allowed them to completely satisfy its domestic demand and even export large quantities of crude oil. The rest of the world became increasingly dependent on crude oil imports, primarily from Venezuela and The Middle East.

After World War II, a period of huge expansion in oil industry has begun. To satisfy demands of world markets, multinational oil companies increased research and crude oil production as well as building of refineries. Huge oil tankers of spectacular dimensions (with capacities up to 500,000 tons) were also designed to help oil transport.

In the early 1960's the The Middle East enormously increased its oil production and has become main supplier of Western Europe and Far East. Simultaneously, it was confirmed that oil reserves in this region increased and that they are the largest in the world today. In the meantime, the Soviet Union successfully developed its own crude oil production that satisfied domestic and Eastern Europe demands.

Until the beginning of 1970's world crude oil market was in hands of multinational oil companies known as "Seven Sisters" (from the USA and Great Britain).

They kept the prices of crude oil very low up to 2.0 USD per barrel. The countries that produced crude oil were making less money than what other countries were making by taxing oil products. This led to establishment of OPEC (Organization of the Petroleum Exporting Countries) in 1960.

Until the 1970's there was no progress in negotiations about crude oil prices and profit distribution between multinational oil companies and OPEC members. In 1971 the decision was made to increase the price of barrel of crude oil to 2.2 USD. In the meantime, Libyan oil fields that belonged to multinational companies were nationalized which dictated new terms in world oil market.

In the beginning of the 1960's, for the very first time the USA started to import crude oil from Mexico and Venezuela.

Crude oil consumption grew enormously and in the 1960 it reached 1.05 billion tons, which was more than total world's consumption until that point. In the 1970, the oil production reached 2.6 billion tons already, and in the 1980 it reached 3.1 billion tons.

This increasing consumption of oil in the beginning of the 1970's brought dramatic changes in commercial relations (prices, taxes, oil reserves ownership) between large oil companies and oil producing countries that benefited from these changes. The demand for crude oil was larger than production.

In 1973, the war between Egypt and Israel brought embargo on oil exports from OPEC members to countries which supported Israel and to oil companies that refused to accept OPEC terms. OPEC also raised an official price of crude oil to 11.65 USD per barrel, which was the situation without precedence in petroleum history. As the basis of new official price Saudi light oil (Arabian light) was used while prices for other types of oil were adjusted according to oil quality, which depended on quantity of sulphur, density, and costs of oil transport to large markets.

The importance of OPEC's price increase was that it was unilateral and that OPEC members no longer negotiated prices with multinational companies. OPEC became the real cartel that had complete control over the oil market. This ended the period during which multinational companies unilaterally controlled oil prices, while OPEC was only sometimes able to veto their decisions. OPEC took over the monopoly that was formerly held by large oil companies, and the oil producing countries became owners of their resources. The time of inexpensive crude oil and energy was over.

This enormous increase of oil prices in 1973, called "the crude oil shock", had several consequences:

- 1974. An establishment of energy saving program (less consumption – better efficiency).
- 1975. Increase in off shore research and exploitation of crude oil.
- 1976. Changes in technological configurations of refineries.

Soon after the first, in 1979 the second crude oil shock followed. After Iranian revolution OPEC raised prices of crude oil to 24 USD per barrel. Iraq-Iran war in the 1980 caused the market conditions to deteriorate even further due to decrease in crude oil supplies of more than 15% of total OPEC's exports, resulting in oil prices increase to unthinkable 36 USD per barrel.

The consequences of the second crude oil shock, unlike the first, were not that far reaching and long lasting. The oil production outside OPEC members, which benefited from increased prices, increased which led to oil price decrease. OPEC's world market share fell to only 27%.

Demand for energy decreased, as a direct result of energy saving policy. Lower demand caused continuous price decreases that led to oil

prices collapse in 1986. The oil was sold for 9.0 USD per barrel that decreased OPEC's power which temporarily lost its ability to control world's oil prices.

The decrease in crude oil prices, led to disappearance of small petroleum companies whose research and production costs were high, while the profitability of worldwide offshore research decreased. Before the end of the 20th century, OPEC was responsible for 40% of total world oil production, while owning near 80% of world's confirmed crude oil reserves.

The third oil shock followed the Gulf War of 1990 when the prices of oil jumped to 40 USD per barrel, falling back to 22-28 USD per barrel in 2001.

The fourth oil shock arrived in 2004 with the war in Iraq when oil prices reached unbelievable 55.4 USD per barrel. Wars in Iraq of 1990 and 2004 were fought primarily because of crude oil. It is important to mention that the crude oil reserves in the The Middle East account for 66% of world's confirmed oil reserves, with Iraq at 11% and Kuwait at 10% respectively.

The fifth oil shock began in 2006 with its culmination in July of 2008 when the price of crude oil at New York Stock Exchange reached 145.26 USD per barrel. The root was in large demand of oil derivatives caused by large rate of expansion in populous countries such as China and India, and insufficient capacities of refineries which were unable to satisfy this large demand. The price of oil was also affected by political and speculative factors of some stockbrokers as well as depreciation of US Dollar. The fact is that the time of inexpensive crude oil is far behind and we are now in an era of exploration of oil from "unconventional" sources, such as oil shells and tar sands, which are becoming economical if the price of oil is above 115 USD per barrel.

One of the biggest economy crises in history started in 2008. The price of crude oil was decreasing even to 45 USD per barrel, since the demand for petroleum products was also going down. In the beginning of 2010 crude oil price and crude oil demand were going up, as China, India and slowly USA were going out of recession.

The oil economy is confronted with several important factors and they are:

- Accelerated consumption of energy.
- Limited supplies of proved conventional hydrocarbons.
- Move towards unconventional sources.
- Political tensions.

Oil as the most important energy source is of great political interest and often a cause for confrontations in the oil rich regions (Kuwait, Iraq) with the goal of securing strategic (energetic) interests of the most developed nations short in crude oil supplies (USA, Great Britain). Having in mind that the oil supplies are decreasing, very important political target, choosing no means, will continue to be to secure provision of oil.

1.2. Research of crude oil and gas

During research of crude oil and gas certain activities are performed that can be categorized into three main groups:

- Basic geological research.
- Structural research of deeper sections using geophysical methods.
- Testing by drilling.

Based on the results in case that crude oil or gas is found in the second phase of research, reserves of crude oil and gas are determined. After this, the work on exploitation of oil or gas begins.

1. Geological research includes study of rocks. Types of rocks are determined based on their origin, composition, structure, geological age and physical properties. Position of visible layers are determined, faults and fault zones are marked. Gathered data are included into a map that represents basis for creating an image on geological conditions in deeper sections (underground) of researched area and it determines a structure of the Earth's crust (fold, fault types, and eventual cover). Based on this a probability for finding oil and gas in an area is determined. Today a lot of this data are quickly gathered by using satellite photos of desired area, which is then to be confirmed on terrain.
2. Geophysical researches based on arrangement of geomagnetic forces or by following propagation of quake waves, which propagate differently in different types of rocks, allow us to determine types of rocks and their positions. This allows us to determine structure of covered parts of land, which is usually confirmed by deep drilling. Geological and geophysical researches provide us with basic data on structural (tectonic) relationship of researched area and potential oil and gas deposits.
3. Samples of rocks are gathered by drilling, which are compared to the results of previously conducted researches (geological and geophysical) and which directly determine potential ap-

pearance of oil and gas. These researches are the most expensive, but most reliable as regards to the result.

If oil and gas are found, research well can often be used as exploitation well.

1.3. Crude oil production

Crude oil deposits are under certain pressures which are in most cases sufficient to push the crude oil all the way out in oil well, and then through it to the surface of the Earth. Crude oil flows to the surface as long as the pressure in deposits is high enough. For such case, we say we get the crude oil by natural eruption. However, the pressure decreases by exhaustion of deposits, and oil flow to surface diminishes. To ensure that the rest of the oil is brought to the surface (10-85%), pumps are built into the well, or either water or gas is introduced under high pressure. In such way, by secondary and tertiary methods of exploitation, oil draw increases.

Crude oil drawn from deposits is collected on the surface in so called "gathering station" which consists of separator and crude oil storage. Gaseous phase can be pumped back into the well with aid of compressors, so the pressure would increase, or it can be delivered to consumers as natural gas by gas pipelines.

Liquid phase (crude oil + water), depending on the water content, is pumped into the dehydration plant. In that plant liquid phase warms up (60-90 °C) and demulsification agent is added. After that, liquid phase is pumped into the storage tank, in which water by standing is separated and it is pumped out into the waste water system. These storage tanks can have volume up to several thousand cubic meters.

Crude oil from storage tanks is taken for analysis. Due to the fact that crude oil quality can vary, sample is taken from bottom, middle, and top of the storage tank. This is how a mean sample is obtained. In this sample, mass portion of water and sediments (salt, mud, and send) in oil is determined, as well as crude oil density. These analyses are needed for sale of crude oil, because at the time of sale, mass of water and sediments is subtracted from total mass of crude oil if they are above declared value.

1.4. Crude oil transport

Crude oil is transported by oil pipelines, tanker ships, and railroad or road tankers from oil fields, places where it is drawn, to refineries, where crude oil is refined.

Crude oil pipeline is the cheapest mean of transportation, and it is used for crude oil transport from oil fields to large sea ports from which crude oil is transported by tanker ships to refineries or terminals (ports for crude oil storage) from where crude oil is again transported by pipelines to refineries inland.

Crude oil transport by railroad or road tankers is more expensive and it is used mostly on shorter distances where there are no pipelines. Important role in crude oil transportation have navigable rivers on which coasts refineries are built. On rivers crude oil is transported by river tanker ships.

1.5. The world crude oil reserves

Relation between confirmed crude oil reserves and consumption had been changing over the years. Increase in crude oil prices to over 30 USD per barrel ensures profitable research and crude oil production off-shore, as well as on-shore in climate unfavorable conditions (Siberia, Alaska, Canada).

With the increase in crude oil prices to over 115 USD per barrel oil production from tar sands and oil shells became profitable, deepwa-

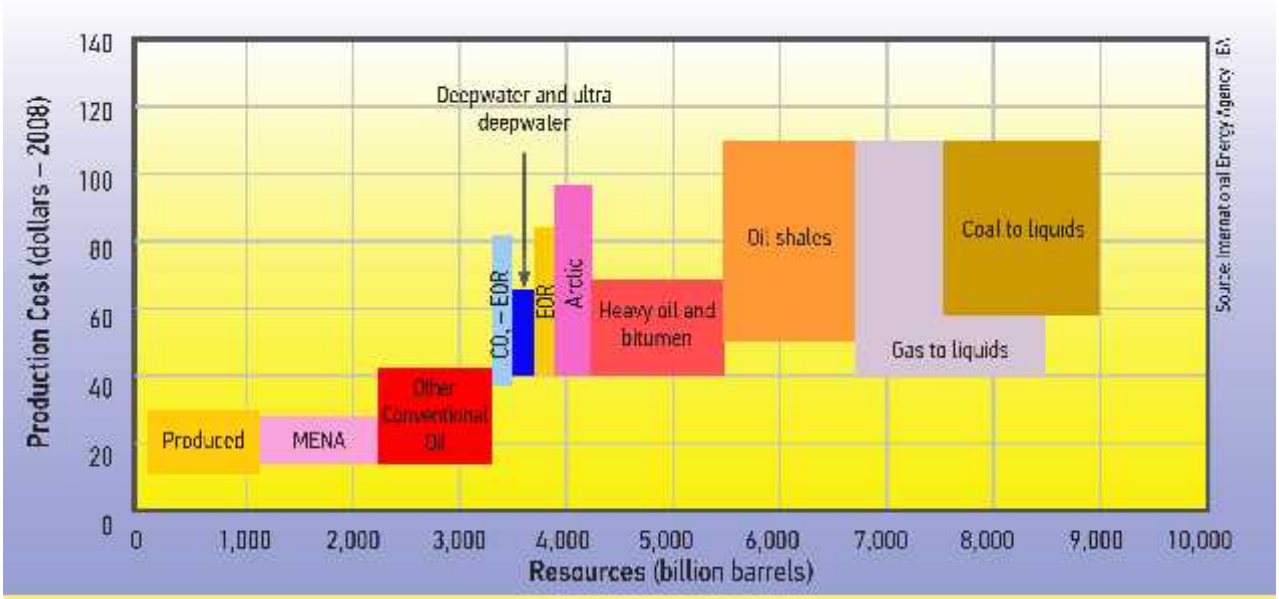


Figure 1 *Production crude oil cost*

ter and ultra deepwater production became profitable with prices over 65-70 USD per barrel, which will additionally increase crude oil reserves (Figure 1).

Proved reserves of conventional and unconventional crude oil are shown in Figure 2.

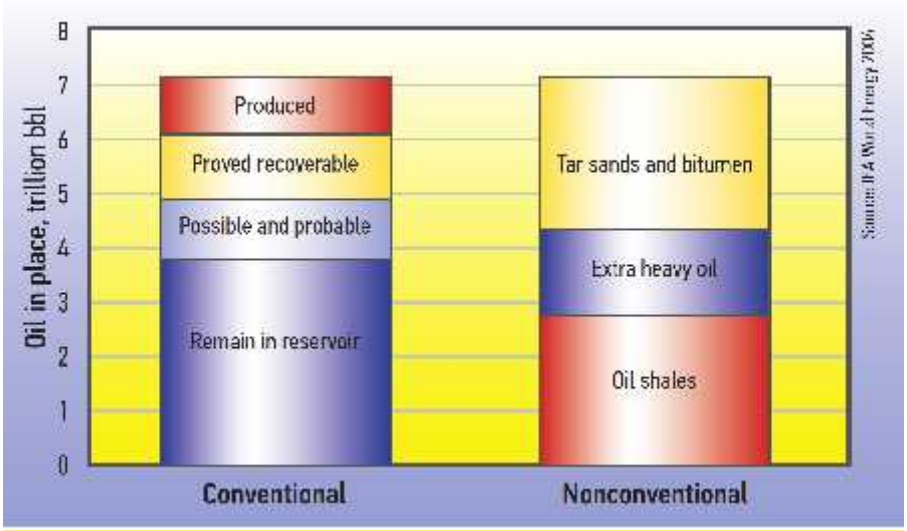


Figure 2 *Proved reserves of conventional and unconventional crude oil*

Figure 2, it can be seen that produced quantities and reserves of conventional crude oil are equal to proved reserves of unconventional crude oil. Further technological advancements are required in order to improve exploitation of oil from unconventional sources, which will assure long lasting supply of crude oil.

Reserves of unconventional crude oil are mostly located in Canada, USA, and Venezuela.

Proved crude oil reserves and their respective locations are shown in figures 3 and 4.

It can be seen that 54.4% of world crude oil reserves is located in the The Middle East, 17.3% in Latin America, 5.4% in North America, 9.5% in Africa, 10.1% in Central and Eastern Europe (former Soviet Union), and 3.3% in Asia. The most developed countries of the world USA, Canada, European Union, India, Japan, and China have only 6.6% of world's crude oil reserves on their territories. Consequently it can be concluded that in near future battles will be fought for crude oil sources in order to allow for further development of the most developed nations.

Nations with the largest oil reserves are shown in Table 1.

From Table 1 it can be seen that between top six nations with conventional crude oil reserves five are from The Middle East.

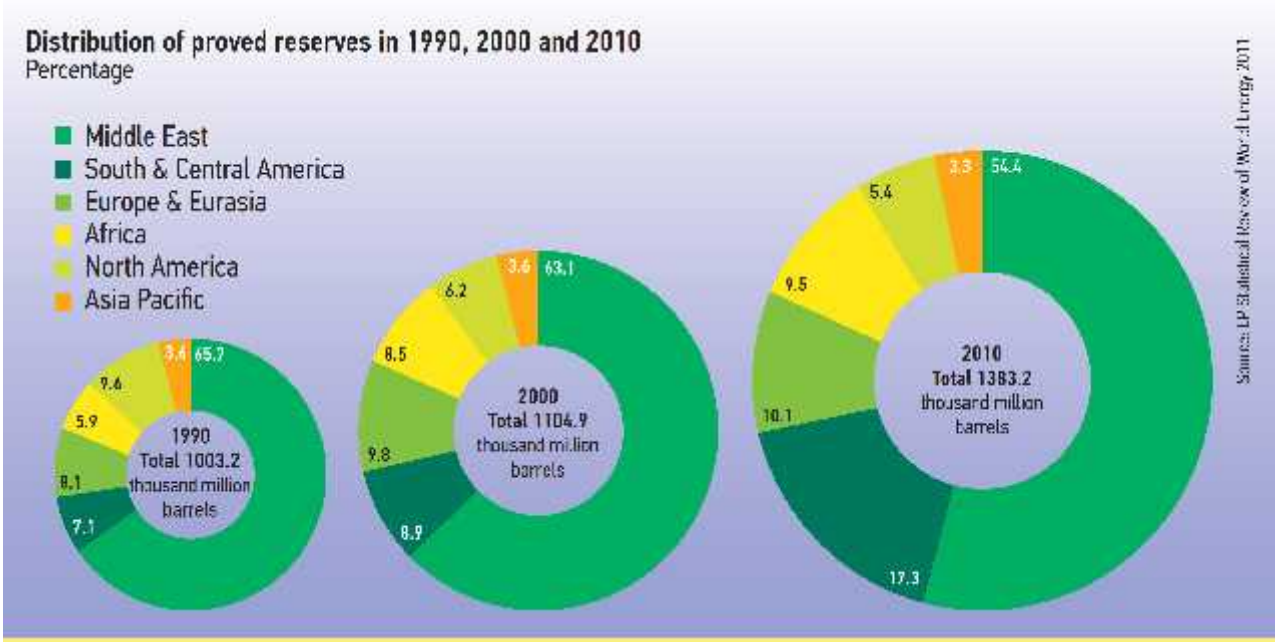


Figure 3 *Proved reserves of conventional crude oil by locations*

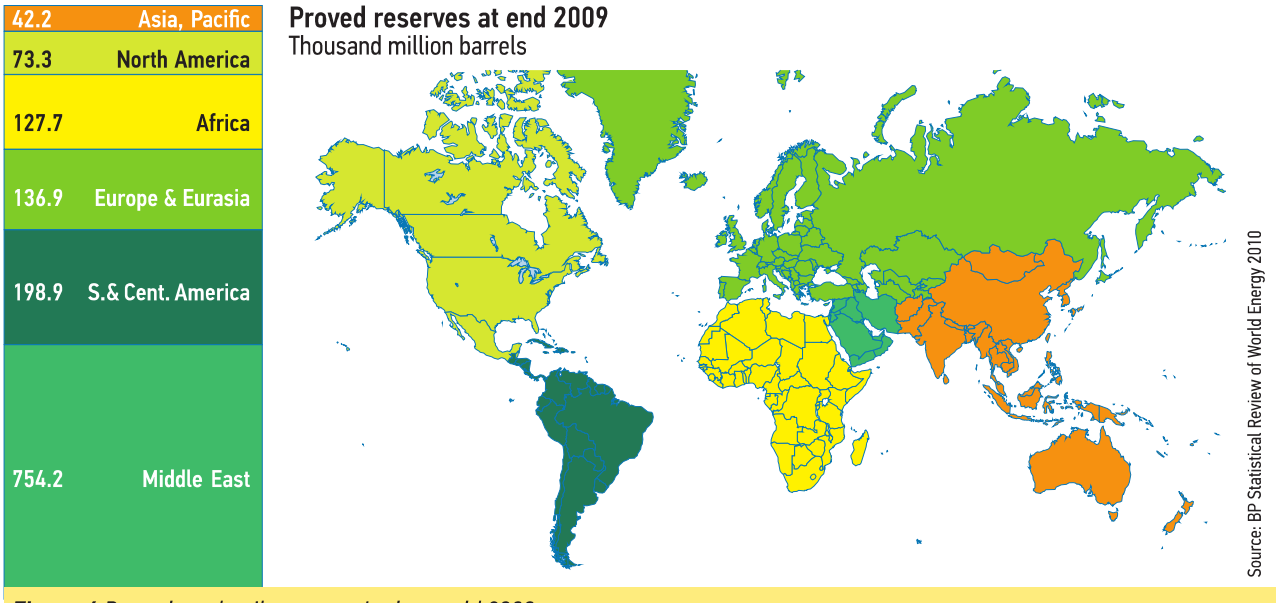


Figure 4 *Proved crude oil reserves in the world 2009*

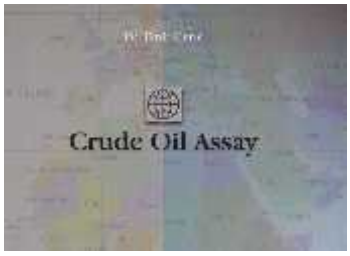
It can be seen that proved crude oil reserves, with current consumption, are sufficient for next 50 years. It is to be expected that demand for crude oil will increase sharply in China and India, the most populated nations of the world, that are experiencing significant economic growth. Due to high crude oil prices, it is to be expected that further exploration of new offshore and onshore oil fields will take place, as well as oil exploitation from oil shells and tar sands, which should satisfy future needs.

Table 1 *Nations with largest conventional crude oil reserves (million barrels)*

Year	2000	2002	2005	2007	2009	2010
Top 20	**963,016**	**978,648**	**1,125,157**	**1,184,500**	**1,295,900**	**1,296,500**
S. Arabia	263,500	261,750	264,200	264,200	264,600	264,500
Venezuela	72,600	77,685	79,700	99,400	211,200	211,200
Iran	89,700	89,700	137,500	138,200	137,000	137,000
Iraq	112,500	112,500	115,000	115,000	115,000	115,000
Kuwait	96,500	96,500	101,500	101,500	101,500	101,500
U.A.E	97,800	97,800	97,800	97,800	97,800	97,800
Russia	48,573	48,573	74,400	80,400	76,700	77,400
Libya	29,500	29,500	39,100	43,700	46,400	46,400
Kazakhstan	5,417	5,417	39,600	39,800	39,800	39,800
Nigeria	22,500	24,000	35,900	36,200	37,200	37,200
Canada	4,931	4,858	16,500	28,600	32,100	32,100
SAD	29,671	30,439	29,350	30,500	30,900	30,900
Qatar	3,700	15,207	15,207	27,400	25,900	25,900
China	24,000	24,000	16,000	16,100	14,800	14,800
Angola	5,412	5,412	9,000	13,500	13,500	13,500
Brazil	7,357	8,465	11,800	12,600	12,900	14,200
Algeria	9,200	9,200	12,200	12,200	12,200	12,200
Mexico	28,400	26,941	13,700	12,200	11,700	11,400
Norway	10,800	9,447	9,700	8,200	7,100	6,700
Azerbaijan	1,178	1,178	7,000	7,000	7,000	7,000
Rest of the world	**61,652**	**61,304**	**75,543**	**76,500**	**81,300**	**86,700**
World	**1,024,668**	**1,039,952**	**1,200,700**	**1,261,000**	**1,376,600**	**1,383,200**

Source: BP Statistical Review of World Energy 2011.

1.6. The world crude oil production



Production of conventional crude oil in the world is three times larger than proved crude oil reserves (barrels/day).

Crude oil production by region is shown in Figure 5.

The biggest productions are in The Middle East, Russia and North America.

World oil production fell by 2.0 million b/d in 2009 the largest decline since 1982. OPEC production fell by 2.5 million b/d. Saudi Arabia output fell by 1.1 million b/d, the world's largest volumetric decline. Russian production increased by 146,000 b/d. Production outside OPEC rosed by 450,000 b/d, led by an increase of 460,000 b/d in the USA, the largest increase in the world and the strongest USA growth since 1970.

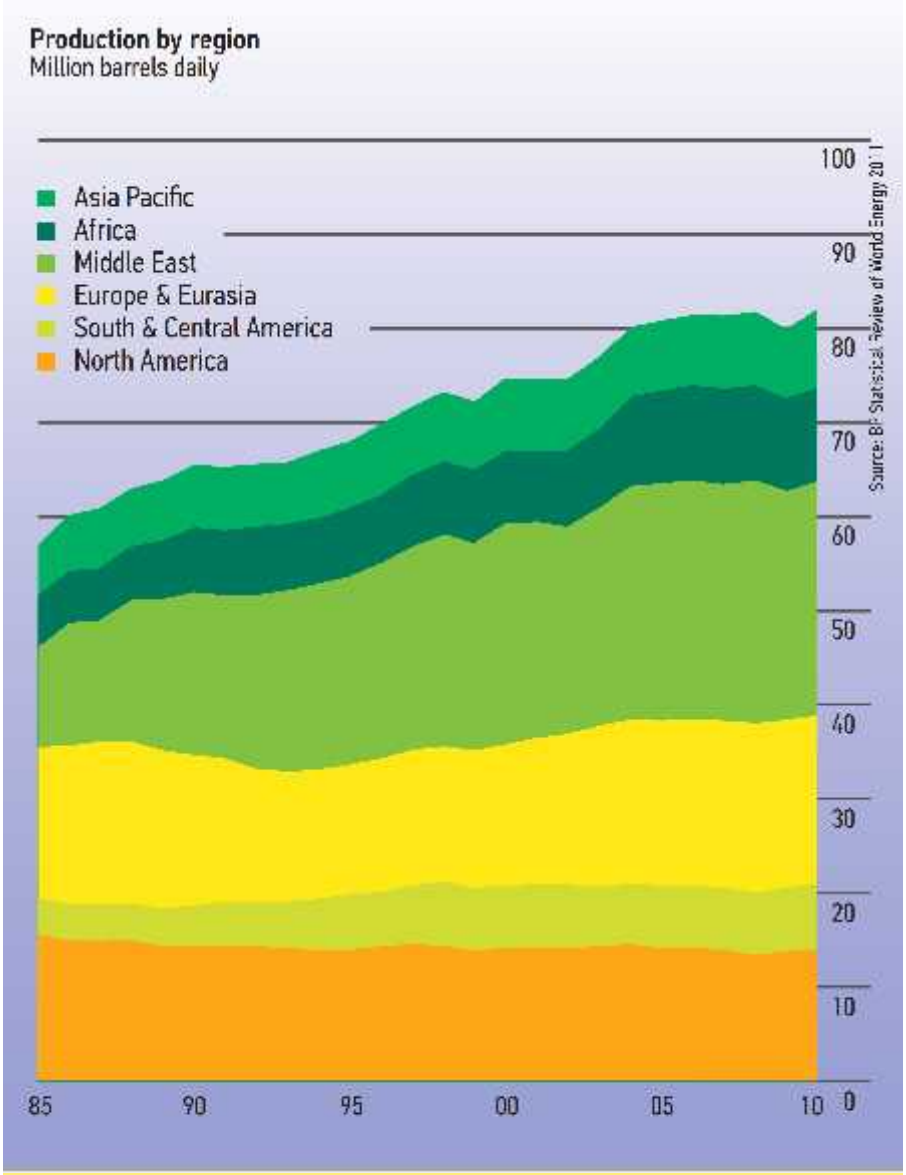


Figure 5 *Crude oil productions by region*

In 2010 world oil production increased by 1.8 million b/d; growth was broadly-based, with increases in all regions eycept Europe & Euroasia. Moreover, growth was broadly split between OPEC and non-OPEC countries.

From Table 2 it can be seen that ten largest producers of crude oil produce 60.7%, while the rest of the world produces 39.3%. Also, it can be seen that oil production has been increasing in Russia, Saudi Arabia, USA, Iran, China, Canada, UAE and Venezuela, while other countries are decreasing the production due to lower proved reserves. The increase or reduction of crude oil production between year 2000 and 2005 was caused by the war in Iraq, increased de-

Table 2 Largest crude oil producers (thousand barrels daily)

Year	2001	2003	2005	2008	2009	2010
First 10	**46,354**	**48,806**	**50,870**	**49,984**	**48,947**	**49,857**
Saudi Arabia	8,819	9,774	10,589	10,846	9,893	10,007
Russia	7,017	8,488	9,482	9,886	10,035	10,270
USA	8,068	7,828	7,291	6,736	7,271	7,513
Iran	3,775	3,959	4,221	4,325	4,199	4,245
China	3,297	3,410	3,617	3,795	3,800	4,071
Canada	2,727	2,996	3,040	3,238	3,224	3,336
Mexico	3,560	3,789	3,760	3,157	2,979	2,958
UAE	2,535	2,671	2,864	2,980	2,750	2,849
Venezuela	3,137	2,627	3,042	2,566	2,438	2,471
Norway	3,419	3,264	2,964	2,455	2,358	2,137
Rest of the world	28,106	29,121	31,398	31,836	31,331	32,238
World	**74,460**	**77,927**	**82,268**	**81,820**	**80,278**	**82,095**

Source: BP Statistical Review of World Energy 2011

mand in China and USA, as well with OPEC's politics of keeping the oil prices stable by regulating production. Considering the proved oil reserves, it is expected that relations between ten largest oil producers with change significantly in near future.

Figure 6 shows production and proved oil reserves.

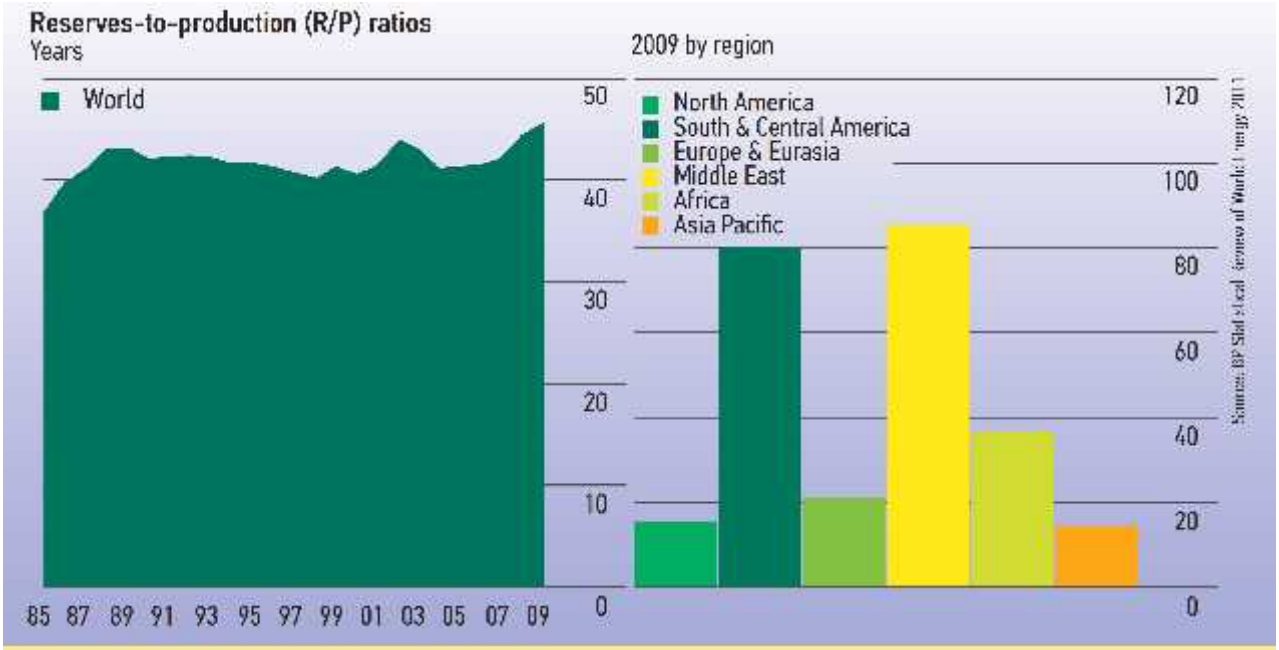


Figure 6 *Courses of production and discovered crude oil reserves*

The global proved oil reserves in 2009 rose by 0.7 billion barrels to 1,333.1 billion barrels, with an R/P ratio of 45.7 years. Increases in Indonesia and Saudi Arabia are more than declines in Norway, Mexico and Vietnam. The 2008 figure has been revised by 74.4 billion barrels, largely due to an increase in Venezuela official reserves.

1.7. Crude oil consumption

The biggest crude oil consumers are the most developed and the most populated countries.

The United States consume about 19 million barrels daily. That's more than the next-four-largest consumers – China, Japan, Russia, and India – combined. Of those 19 million barrels, 56% are imported. The imports alone represent more oil than Saudi Arabia produces in a day; in fact, it accounts for nearly 20% of the world's entire production. In the last 11 years, China has experienced the largest growth in oil consumption (55%).Countries such as Japan, Germany and Canada are experiencing lower consumption of oil due to better energy efficiency, savings in consumption, and larger consumption of natural gas. Ten largest crude oil consumers are consuming about 58% of world's total consumption.

The largest oil consumers are shown in table 3.

Table 3 *Largest crude oil consumers (1000 barrels/day)*

Year	1994	%	2003	%	2007	%	2009	%	2010	%
First 10	41,005	60.0	47,122	59.9	50,645	59.7	48,819	57.6	50.873	58.2
USA	17,719	25.9	20,033	25.5	20,680	24.4	18,771	22.2	19,148	21.9
China	3,116	4.5	5,803	7.4	8,066	9.5	8,201	9.7	9,057	10.4
Japan	5,746	8.4	5,455	6.9	5,039	5.9	4,391	5.2	4,451	5.1
India	1,413	2.1	2,420	3.1	2,748	3.2	3,211	3.8	3,319	3.8
Russia	3,359	4.9	2,645	3.4	2,706	3.2	2,936	3.5	3,199	3.7
Germany	2,880	4.2	2,664	3.4	2,393	2.8	2,409	2.8	2,441	2.8
Brazil	1,418	2.1	1,785	2.3	2,274	2.7	2,399	2.8	2,604	3.0
Canada	1,742	2.5	2,132	2.7	2,323	2.7	2,179	2.6	2,276	2.6
South Korea	1,840	2.7	2,300	2.9	2,389	2.8	2,326	2.7	2,384	2.7
Mexico	1,772	2.6	1,885	2.4	2,027	2.4	1,996	2.4	1,994	2.3
Rest of the world	27,348	40.0	31,533	40.1	34,233	40.3	35,895	42.4	36,509	41.8
World	68,353	100.0	78,655	100.0	84,878	100.0	84,714	100.0	87,382	100.0

Source: BP Statistical Review of World Energy 2011

Consumption by region is shown on figure 7.

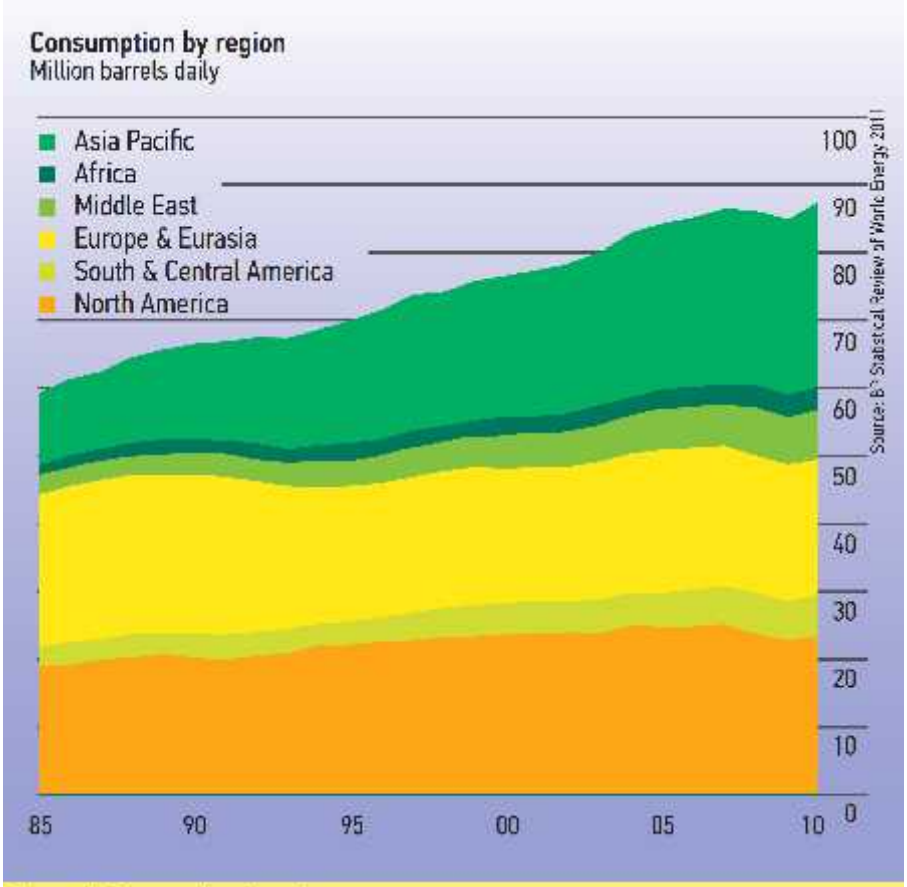


Figure 7 Consumption by region

World oil consumption increased in 2010 by 2.7 million b/d; growth was above average in all regions, although Asia Pacific countries accounted for the majority (54%) of global consumption growth.

1.8. Flows of crude oil supply

The following is the description of oil supplies for OPEC member and non-OPEC member countries.

1.8.1. Flows of oil supplies for non-OPEC members

Countries that are not OPEC members, except for Russia and Kazakhstan, show decrease of oil reserves of about 50%-60%. It is expected this decrease will continue at an annual rate of 5%.

Figure 8 shows decrease of oil production for non-OPEC members, without former USSR.

By late 1990's existing production was increasing at an annual rate of 4-7%.

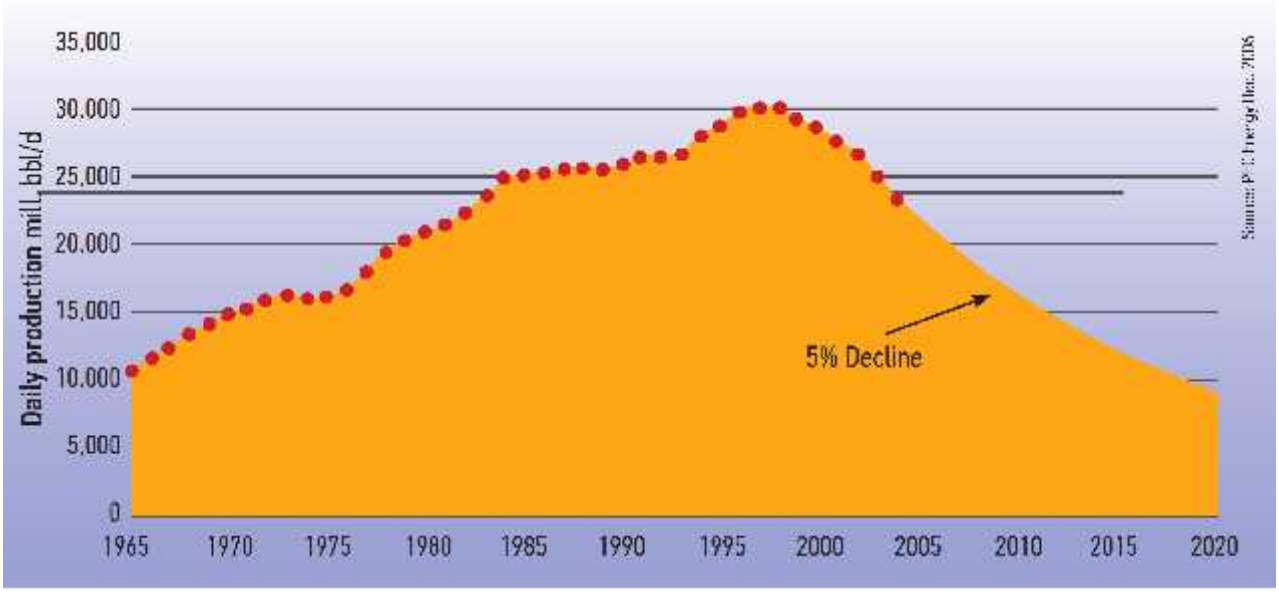


Figure 8 *Expected decrease in oil production for non-OPEC members*

In 2020, daily production of oil in these countries will be decreasing at a rate of 5% and will amount to about 9,000 million barrels per day.

In Russia and Caspian region (Azerbaijan and Kazakhstan), based on successfully completed projects and findings of new oil sources, oil production will be increasing up to 3.0 million barrels per day.

In non-OPEC nations, significant increase in production of natural gas and condensates (Russia) is expected, as well as production of unconventional oil (Canada, USA).

1.8.2. Flows of oil supplies for OPEC members

Production of oil in OPEC member countries will increase depending on the region:

In Africa, the production will increase in Algeria and Libya, but at much lower rate than in last several years, while in Nigeria production in the next 10 years will increase by 1.0 million barrels per day despite political uncertainty. In Angola, oil production will also increase due to newly discovered oil sources.

In Venezuela, South America, discovery of new oil deposits will end the negative production trend which was recorded in the last several years. In Brazil, production will also increase due to discovered oil deposits.

In the The Middle East, the region with the largest oil reserves, production will increase continually.

1.8.3. Flows of world's oil supplies in 2009

Figure 9 shows flows of crude oil supplies in 2009.

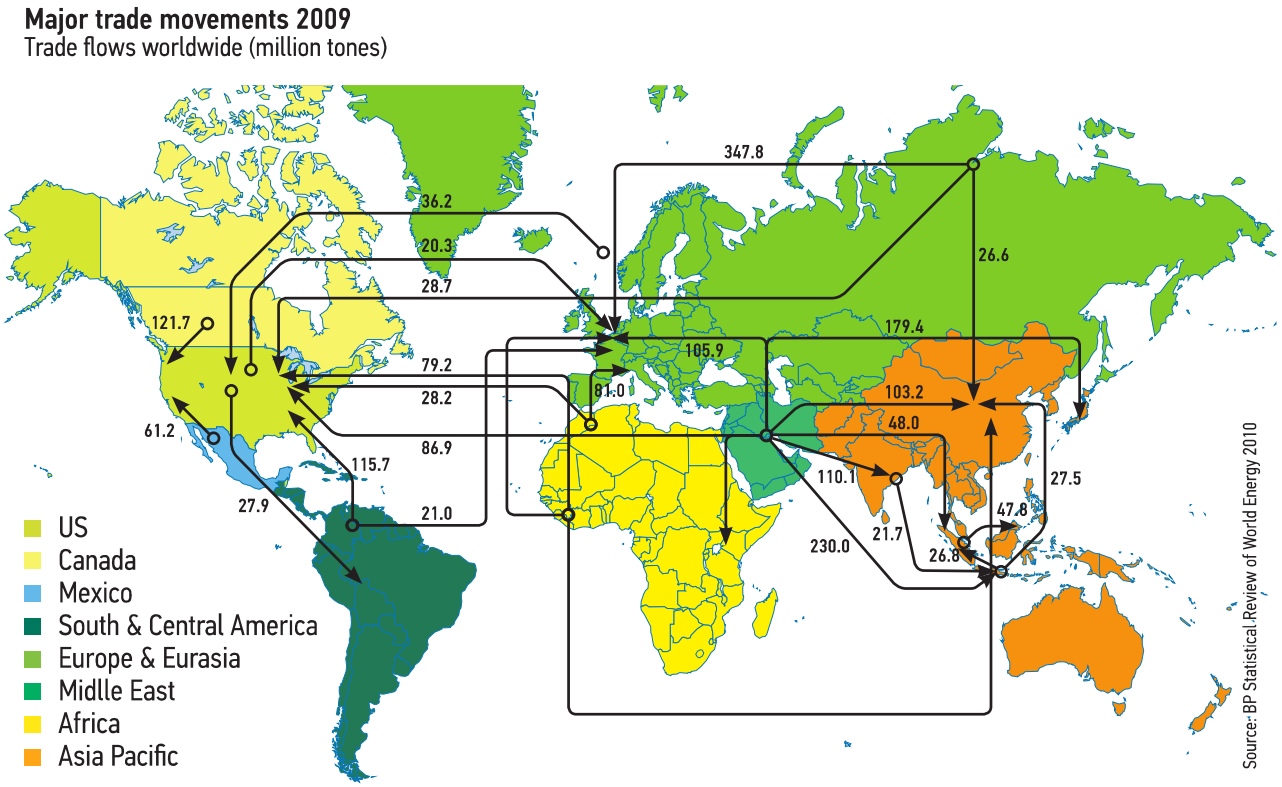


Figure 9 Crude oil flows in 2009 (million tones daily)

The largest oil consumer in the world, USA, besides its own production, in 2009 was importing oil from Canada, Latin America, Western Africa, Northern Africa, The Middle East and Russia.

Total crude oil imports in 2009 in USA were 8,893 thousand barrels daily. Domestic crude oil production in 2009 was 7,196 thousand barrels daily. Total processing of crude oil in USA 2009 was 14,313 thousand barrels daily. At the same time US exported 44 thousand barrels of crude oil daily. Also US imported 122.0 millions tones or 2,550 thousand barrels of products daily and exported 89.5 million tones or 1,871 thousand barrels of products daily.

Total consumption of crude oil and its derivatives in USA in 2009 was 842.9 tones or 18.686 barrels daily. This means that besides imported of crude oil, the United States also imported products, mostly gasoline.

In 2009 *Europe* imported 513.3 million tones or 10,308 thousand barrels daily of crude oil mostly from Former Soviet Union, The Middle

East and North Africa. Europe also imported 152.0 million tones or 3,177 thousand barrels daily of products mostly from Former Soviet Union. In 2009 Europe also exported 23.1 million tones or 464 thousand barrels daily of crude oil and 72.9 million tones or 1,523 thousand barrels daily of products, mostly to US and North Africa. Total import of crude oil and products in 2009 was 665.3 million tones or 13,485 thousand barrels daily and total export was 96 million tones or 3,725 thousand barrels daily.

Total crude oil products consumption in Europe in 2009 was 88.6 million tones or 18,530 thousand barrels daily. The difference between import and export is domestic crude oil production.

In 2009 *China* imported 203.5 million tones or 4,086 thousand barrels daily of crude oil crude oil from The Middle East, Western Africa and Russia.

China also imported 49.8 million tones or 1,041 thousand barrels daily of products mostly from Japan and Singapore.

In 2009 China also exported 4.7 million tones or 94 thousand barrels daily of crude oil and 29.4 million tones or 614 thousand barrels daily of products.

In 2009 China's own production of crude oil amounted to 3.795 million barrels daily, while its consumption of crude oil and its derivatives amounted to 8.293 million barrels daily.

In 2009 *Japan* imported 176.5 million tones or 3.545 thousand barrels daily of crude oil, mostly from The Middle East.

Japan also imported 35.3 million tones or 738 thousand barrels daily of products, mostly from Singapore.

In 2009 Japan also exported 16.5 million tones or 345 thousand barrels daily of products.

In 2009 *India* imported 145.8 million tones or 2.928 thousand barrels daily of crude oil, mostly from The Middle East and Western Africa.

India's own production of crude oil amounted to 35.4 million tones or 754 thousand barrels daily, while its consumption of crude and its derivatives amounted to 2,882 million barrels daily. India also imported 10.4 million tones or 217 thousand barrels daily of products.

On all that is described above, we can conclude that the most developed countries of the world also import the largest amounts of crude oil. This amount will increase from year to year depending on the level of development of each country.

1.8.4. Crude oil flows in near future

Based on given data and findings, possible future flows of crude oil distribution are shown in the Figure 10, which will primarily depend on geopolitical conditions. In case that anticipated scenarios do not become true, especially in the case of crude oil distribution to USA from Latin America, it will again come to redistribution in crude oil supplies or new wars in order to secure them.

In general, it can be summarized:

- Supplies of crude oil to the USA from Canada and Latin America will increase. West Africa will compensate decrease of its crude oil supplies to the USA from North Sea, and supplies of crude oil from The Middle East will decrease.
- Supplies of crude oil from Former Soviet Union countries to Europe will increase, while supplies from The Middle East will decrease.
- In Asia, crude oil supplies will increase from The Middle East, West Africa, and to some extent from Russia, due to logistical limits. Latin America will also provide limited supplies for crude oil to Asia.

s largest oil companies, (Exxon-Mobil, Chevron-Texaco, and Conoco-Philips) are the U.S. companies, which have franchise for crude oil exploration and production around the world. Consequently, the USA will be the first country these companies secure crude oil supplies for.

In respect to proven conventional crude oil reserves (Figure 3 and Table 1.) and predicted crude oil supplies (Figure 10), the major crude oil exporters will have crude oil for export (their own consumption not included):

- The Middle East for 45 years.
- Former Soviet Union for 19 years.

As shown in Figure 10, if geopolitical situation is stable, the United States will secure crude oil supplies from Canada, Latin America, The Middle East, West Africa, North Africa and Russia.

In addition to crude oil, USA will import major quantities of petroleum products, especially motor gasoline and gas oil, from Europe and The Middle East.

Europe will import crude oil mostly from Former Soviet Union, The Middle East, North and West Africa.

Crude oil distribution from The Middle East to Europe will depend on geopolitical conditions, which include safe delivery of crude oil

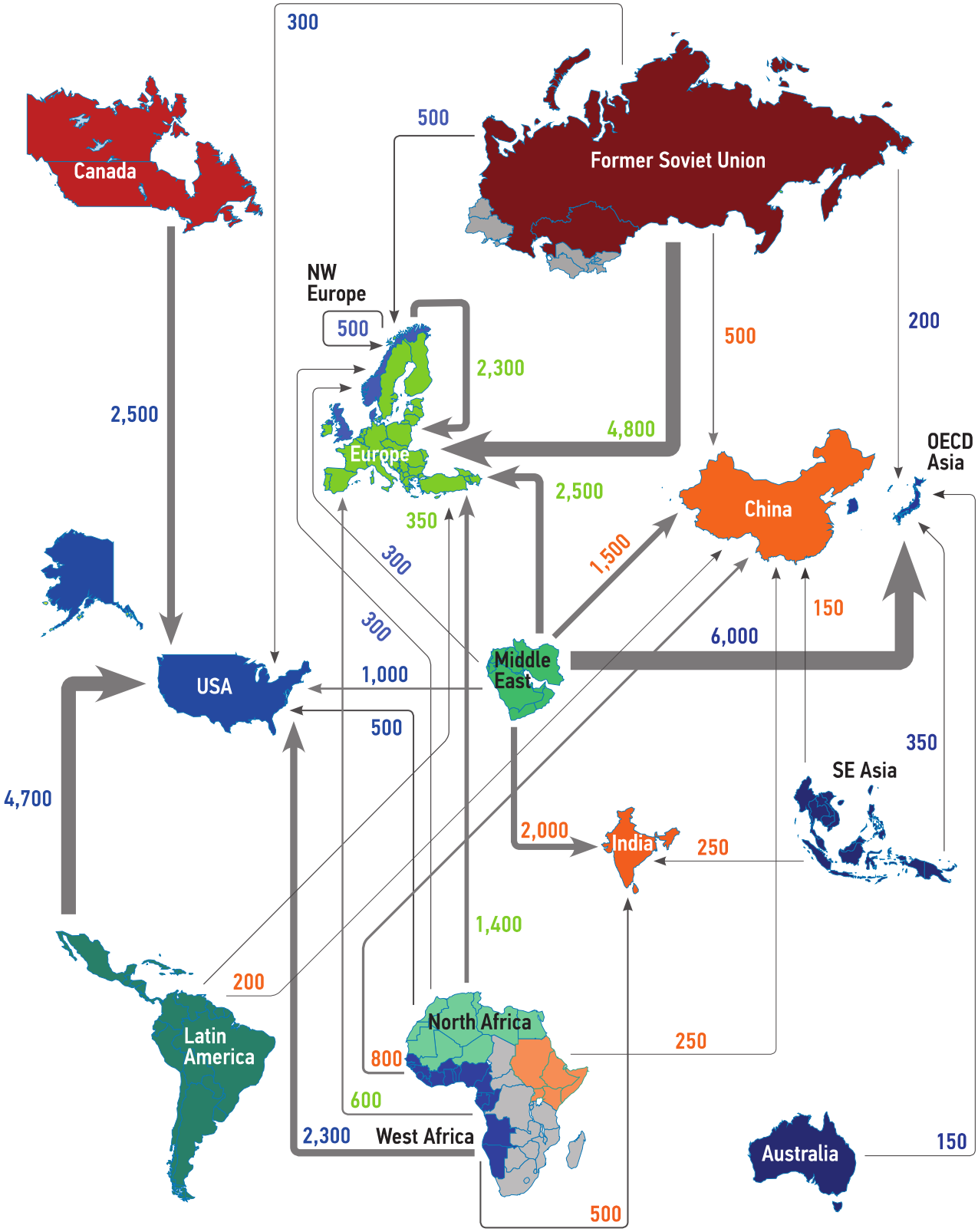


Figure 10 Foreseen possible future crude oil flows

to USA with predicted future flow of crude oil, as well as delivery of crude oil to China and India, countries with growing economies. If there occurs disturbance in geopolitical situation, then distribution of crude oil from The Middle East to Europe will be uncertain.

1.8.5. Crude oil flows – Alternatives

China and Japan growing economies will depend on security and duration of crude oil supply from The Middle East, currently their main crude oil supplier. Since The Middle East will also supply the USA, India, Europe; China and Japan should find additional crude oil sources in order to diversify oil supply. Russia is seen as the most natural oil source due to its geographic proximity and new crude oil deposits Far East (East Siberia, Sakhalin, Kamchatka), Figure 11.

Figure 11 Connecting Far East by oil pipelines

Nevertheless, that requires construction of pipelines to Chinese border and port in Japanese Sea.

Russia is currently constructing this oil pipeline in order to increase areas of strategic interest (China, Japan). This course of actions will increase competition between crude oil suppliers to Asia, and will consequently ensure increase of oil supplies to Europe from Saudi Arabia.

US companies have concession for crude oil exploration at Sakhalin. Some of that oil, they will deliver to USA. That will to some extent diminish USA oil dependence from politically unstable Latin America.

1.9. Crude oils quality

In the world, quality of crude oils constantly deteriorates because of the increase of sulphur content in oil and increase in oil density.

Based on proven conventional crude oil reserves, it is to be expected that the quality of crude oil will deteriorate even more in future.

Figure 12 shows quality of crude oil in the last ten years based on density, while Figure 13 shows quality based on sulphur content.

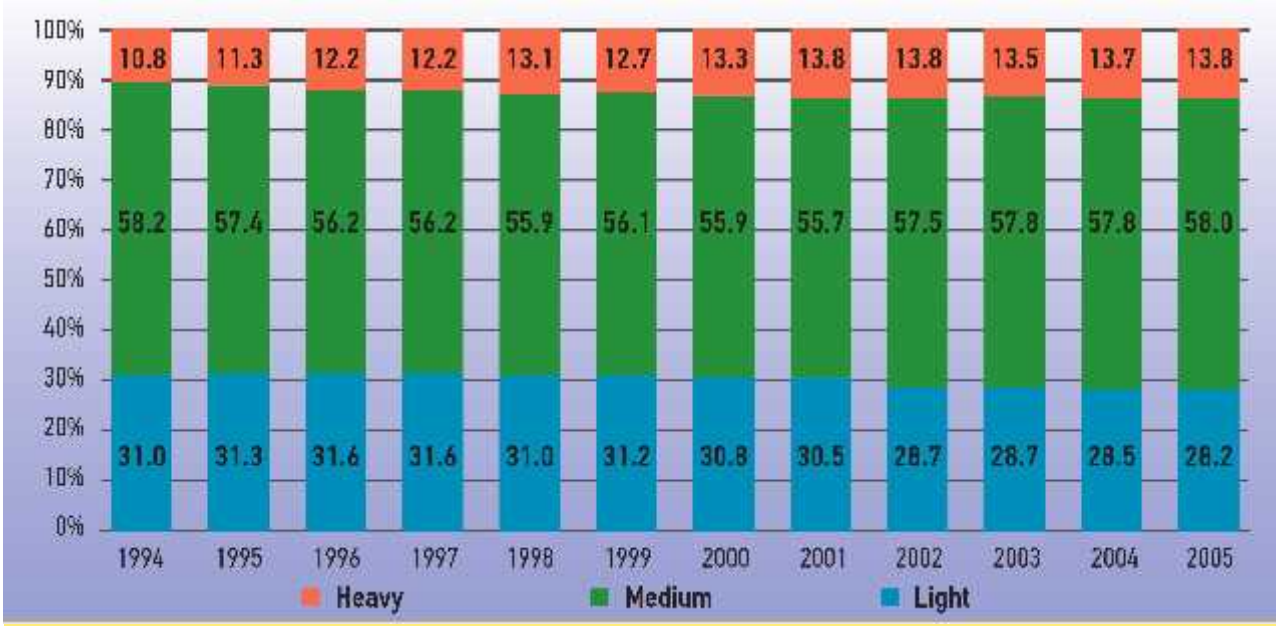


Figure 12 Quality of crude oil based on density

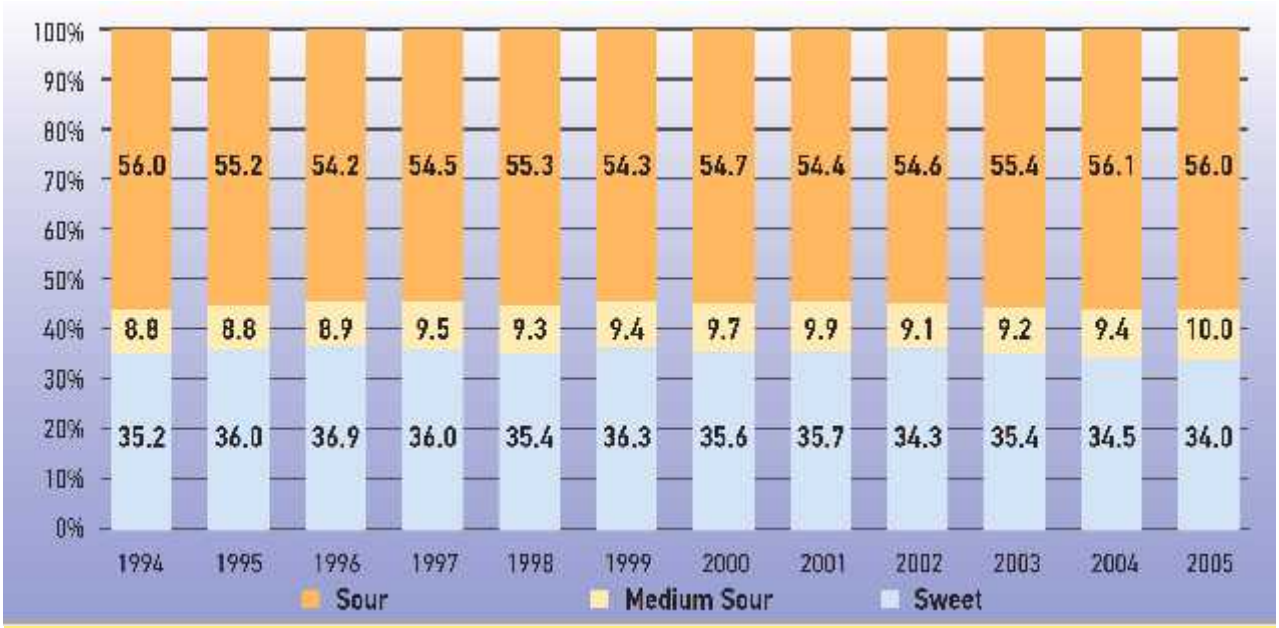


Figure 13 Quality of crude oil based on sulphur content

It is apparent that light crude oils share constantly decreases, while share of medium and heavy crude oils increases. It is also apparent that "acid" and medium "acid" crude oils are more present than "sweet" crude oils.

Crude oils with higher density have higher residue content (atmospheric and vacuum residue), and lower content of so called "white" products than crude oils with lower density. Based on quality of available crude oil, technology is adjusted that will in accordance with the market's needs, produce sufficient quantities of products that will satisfy requested quality.

Quality of crude oil has been changing in the last 40 years, and it will keep changing in the future. Coming to sulphur content and density, the quality of refined oils was better in the past compared to quality of present and future oils. In the past, crude oils had lower sulphur content and higher density when expressed in °API, while lower density when expressed in kg/m^3. Such oils, due to lower sulphur content, were easier and cheaper to refine in order to satisfy quality requirements at that time. Additionally, due to their higher density expressed in °API, crude oils had higher content of gasoline and gas oils, and less fuel oils, which was favorable.

Crude oils that are refined today, as well as future crude oils, are heavier and have higher sulphur content. When refining of crude oils from oil shells and tar sands begins, they will be even heavier and with higher sulphur content than today.

It is expected that sulphur content in oil will be 13% higher, and average density 4.4% lower. Based on these data, future technological configuration of refineries needs to be adjusted. Conversion processes (hydrocracking, coking, and IGCC) and processes of hydrodesulphurization will be dominant in oil refining.

Quality of crude oils in The Middle East is getting worse. Crude oils have higher density and higher sulphur content (Figure 14). Since total proven world's conventional crude oil reserves are the highest in The Middle East (60%), quality of crude oils will be deteriorating.

Crude oils qualities that are refined and will be refined in Europe are shown in Table 4.

Europe will get crude oil supplies from Former Soviet Union, The Middle East, and North Africa, and quality of the oil will be will be deteriorating.

Table 4 *Crude oils qualities for refining in Europe*

Properties	1990	2000	2005	2010	2015
Density, ^{O}API	36.8	35.1	33.9	33.4	32.9
Sulphur, w/w %	0.9	1.1	1.2	1.3	1.5

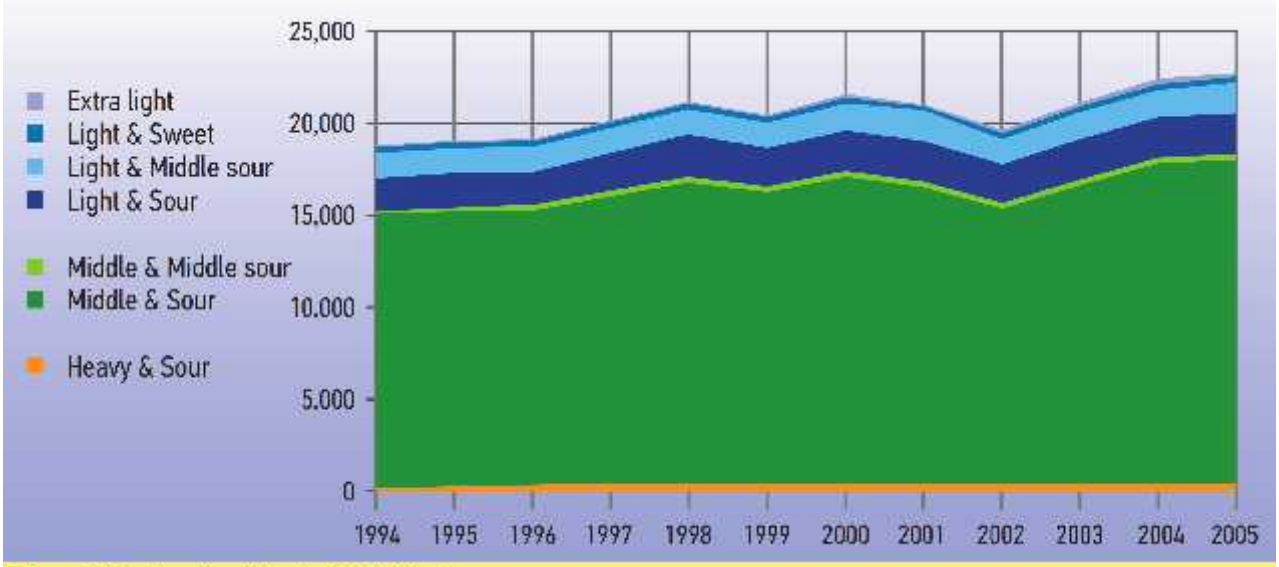


Figure 14 Crude oil qualities in The Middle East

1.10. Prices of crude oil

Prices of crude oil primarily depend on supply, demand, and geopolitical factors.

Figure 15 shows movement of crude oil prices with causes for increases and decreases.

It is evident that Iranian revolution, the Gulf war, war in Iraq, weather disasters in the gulf of Mexico, enormous increase in demand for petroleum derivatives in China and USA, as well as limited production of crude oil and its derivatives in 2006 led to enormous increase of oil prices to 78 USD per barrel, while in 1986 due to raise in unusable refinery capacities and a decision of Saudi Arabia to control the oil market, the prices of oil fell to 12 USD per barrel, and in 1988 the oil prices fell to 10 USD per barrel due to Asian and Russian crisis as their economies collapsed. The prices of oil also fell in the aftermath of terrorist attack on New York.

In 2008, the price of crude oil reached by then unimaginable 145 USD per barrel, but started big recession, first in US and than in all World. The price of crude oil was going down until 45 $/bbl.

Future oil prices will primarily depend on geopolitical conditions and then on production/consumption ratio, unusable refinery capacities, and availability of oil (supplies).

Figure 16 show possible scenarios for movement of oil prices.

According to the actual knowledge it is expected that the most likely scenario will be the one with the highest oil prices of above 100 USD per barrel.

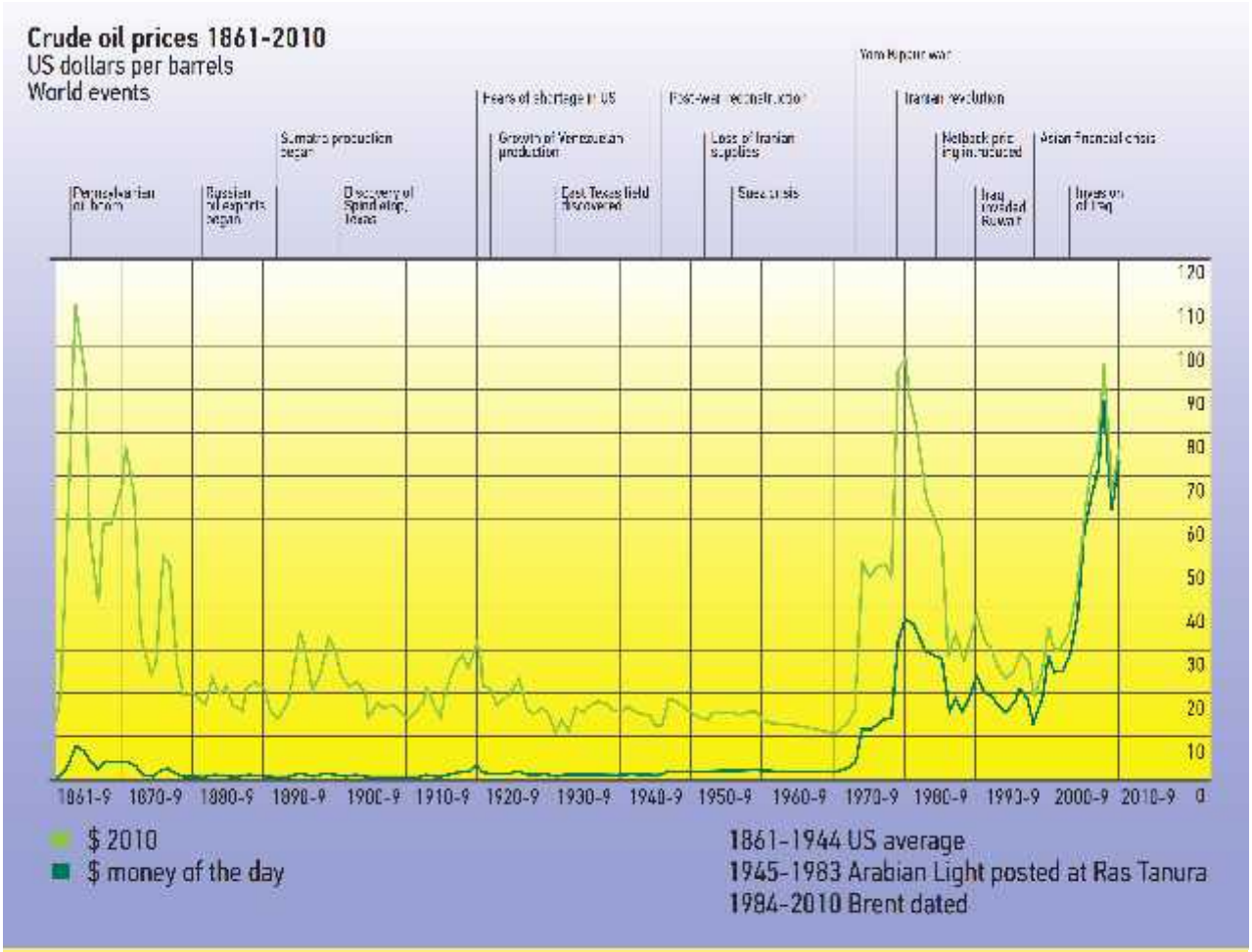


Figure 15 *Movement of crude oil prices*

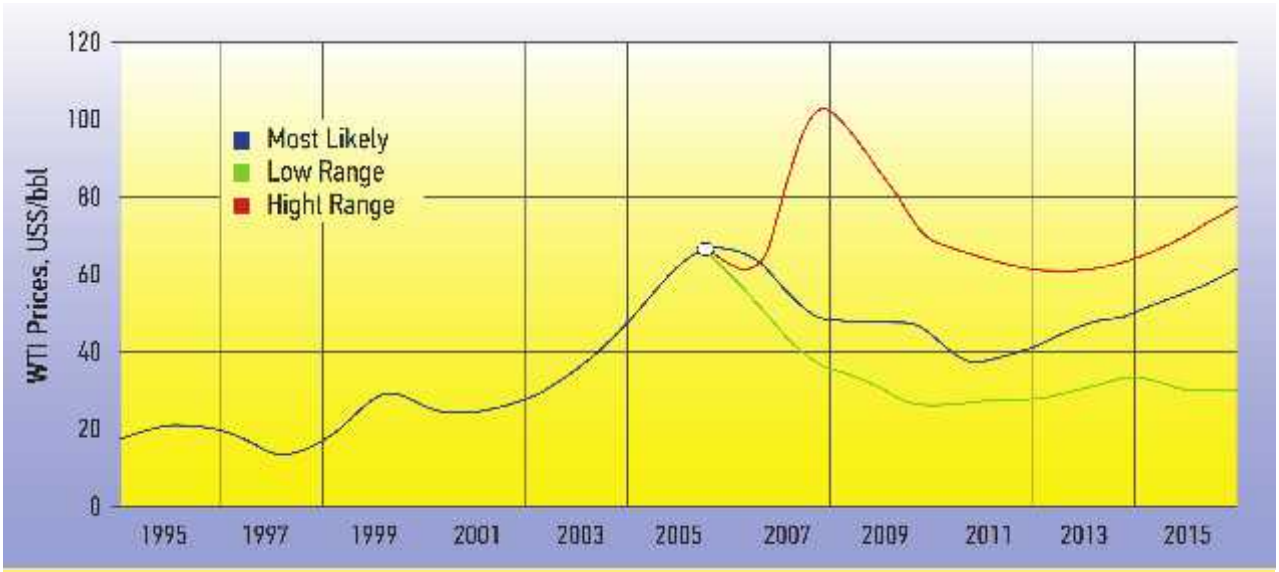


Figure 16 *Possible scenarios for future oil prices movement*

The prices of crude oil will inevitably increase, especially considering decrease in supplies of conventional oil, and increasing use of unconventional oil which production is very expensive.

1.11. Petroleum products market

When industrial production of oil started in the second half of the 19th century, oil derivatives in use were kerosene which was used for illumination, oil which was used for lubrication, and bitumen. These products were produced by distillation in retorts. Products like fuel and gas oils, which had no real use, were either discarded or used as fuels. With the discovery and use of internal combustion engines (Otto and Diesel), fuels and gas oils started being utilized. Soon, coil was completely replaced with fuel oil for ship engines and in industrial use. Parallel to this, new technological processes were being developed which satisfied the market quantitatively and qualitatively. Refineries were being built near oil sources, in places where oil was easily transportable to by ship, train, or pipeline, or near consumption centers.

Quality of petroleum products followed the development and requirements of oil consumers as well as environmental regulations.

The prices of oil after the first oil shock had large impact on the development of oil refineries. Existing facilities were reconstructed in order to decrease energy consumption and increase efficiency. New conversional processes are being built with a goal to increase production of fuels and gas oils which would increase profitability of the refineries. The first oil shock, and especially the second one, considerably affected the pattern of oil products consumption, as a consequence of energy savings and partial substitution with other energy sources (natural gas). Ever increasing demand for virgin naphtha as a resource for petrochemical industry which, after the year of 2000, is expanding again. In automobile industry, we can see increase in diesel engine and reduction in gasoline engine production, which is reflected in considerably larger consumption of diesel oil and slowdown in increase of gasoline fuels consumption. Civil aviation, economies, and tourism are continually increasing, which leads to increase in consumption of jet fuels.

Gasification of industry and consumers led to decrease in consumption of fuel oil.

Share of crude oil in energy consumption is decreasing compared to natural gas and electrical energy.

What is to be expected is gradual introduction of biofuels produced from agricultures (rapeseed or canola), as well as forest and organic waste.

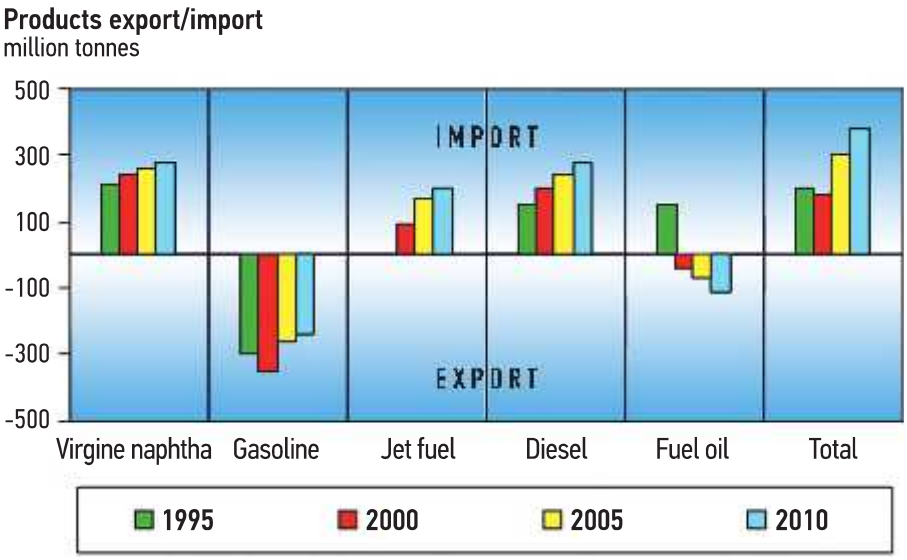


Figure 17 Balance of derivatives in EU (imports/exports)

Figure 17 shows the balance of imports and exports of the derivatives for 12 members of the EU.

It can be seen that EU will experience shortages of basic gasoline, jet and diesel fuels, and surplus in gasoline and fuel oil. These market requirements require adjustment of the technological structure of refineries, which means creation of hydrocracking process of vacuum gas oils in order to increase production of jet and diesel fuels, as well as creation of conversion processes (hydrocracking of vacuum residue, coking of vacuum residue) in order to decrease production of fuel oils and increase production of so-called white products.

Proportion in consumption of specific types of oil products is shown in table 5 and figure 18.

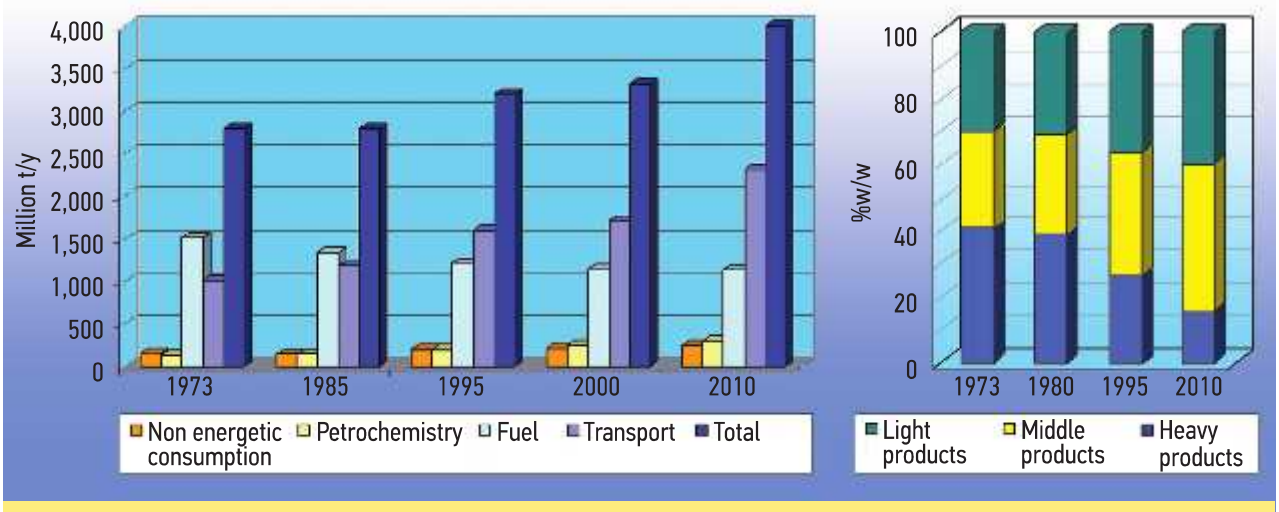


Figure 18 Structure of world petroleum consumption

Table 5 Structure of world consumption petroleum products (106 t/y)

Consumers	1973	1985	1995	2000	2010
Transportation	1,010	1,180	1,600	1,710	2,320
Petro-chemistry	125	140	192	250	300
Non-energetic consumption	155	140	192	215	250
Fuels	1,510	1,340	1,216	1,145	1,130
Total	2,800	2,800	3,200	3,320	4,000
Transportation share, %	36	42	50	52	58

More than 50% of oil derivatives are being used for transportation. Further increase in use of oil derivatives for transportation is expected, because no substitution with other fuels, except partially with bio-diesels, is expected. Also, increase in use of natural gas and electrical energy is expected.

In figure 18 we can see increase in consumption of light (LPG and gasoline) and middle distillates (gas oils) as well as significant decrease of heavy products (fuel oils). Market for petroleum products has been changing from year to year. With the increase in oil prices, refinery technology changes too, in order to provide maximum extraction ratio of so-called "white" products which are more demanded and significantly more expensive than fuel oils. Fuel oils are being replaced with natural gas which is ecologically more acceptable, resulting in significantly lower demand for fuel oils from year to year.

Demand for motor gasoline decreases from year to year while demand for jet and diesel fuels increases. In order for refineries to meet market demands for diesel fuels, they need to build units (hydrocracking of vacuum fuel oils and vacuum residue) that will provide better extraction ratio of "white" products and fuel oils.

Prognosis of demand for petroleum products are based on:

- Integrated access to motor fuels which includes changes to type and efficiency of vehicles, as well as introduction of alternative fuels (LPG, biofuels).
- Available data for particular countries (economic growth, population increase, taxes, regulations, and price predictions).
- Forecasts of demand for heavy fuel oils including trends in coil power plants and bunker ships market.
- Forecasts of demand for virgin naphtha based on analysis in petrochemical industry and new projects.
- Structural market changes are also included.

Figure 19 shows global market demands for petroleum products.

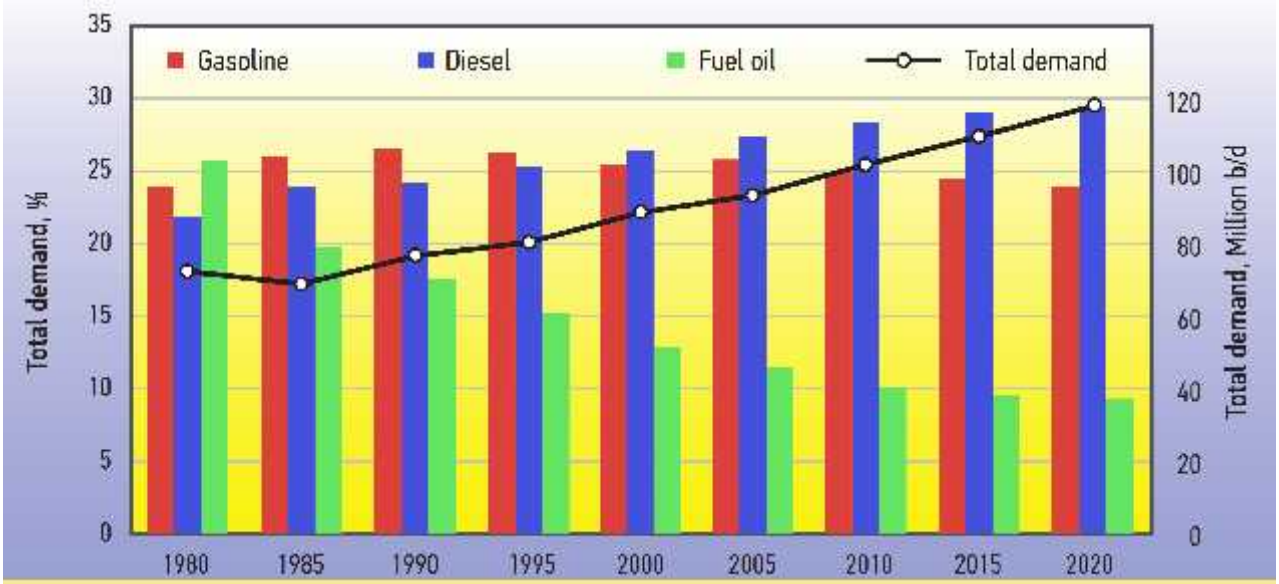


Figure 19 Global needs for the derivatives

Demand for petroleum products in specific regions is different. Some regions use more gasoline (North America), while others use more diesel fuels (Europe).

1.12. Regional consumption of petroleum products

Products balance in specific region depends primarily on market demand, availability of oil, as well as availability of adequate refining technology.

USA consumes enormous qualities of gasoline which, with their installed technology and available refining capacities, they cannot produce, so they import it.

Europe in the middle of the 90's in the 20th century started importing gas oils for production of jet and diesel fuels due to inadequate refining technology which prevents larger production of gas oils. In Europe, as well as in North America, units for fluid catalytic cracking were being built, which allowed for larger production of gasoline, due to them being cheaper to build than facilities for hydrocracking which allow for larger production of gas oils. In the beginning of the 21st century, construction of increasing number of hydrocracking units began in Europe, especially in Italy, Russia, Romania and Poland, countries that have surplus of gas oils for export.

Figure 20 shows petroleum products consumption by region.

Consumption growth was below the 10-years average for all refined product groups. Middle distillates consumption declined in 2009 for

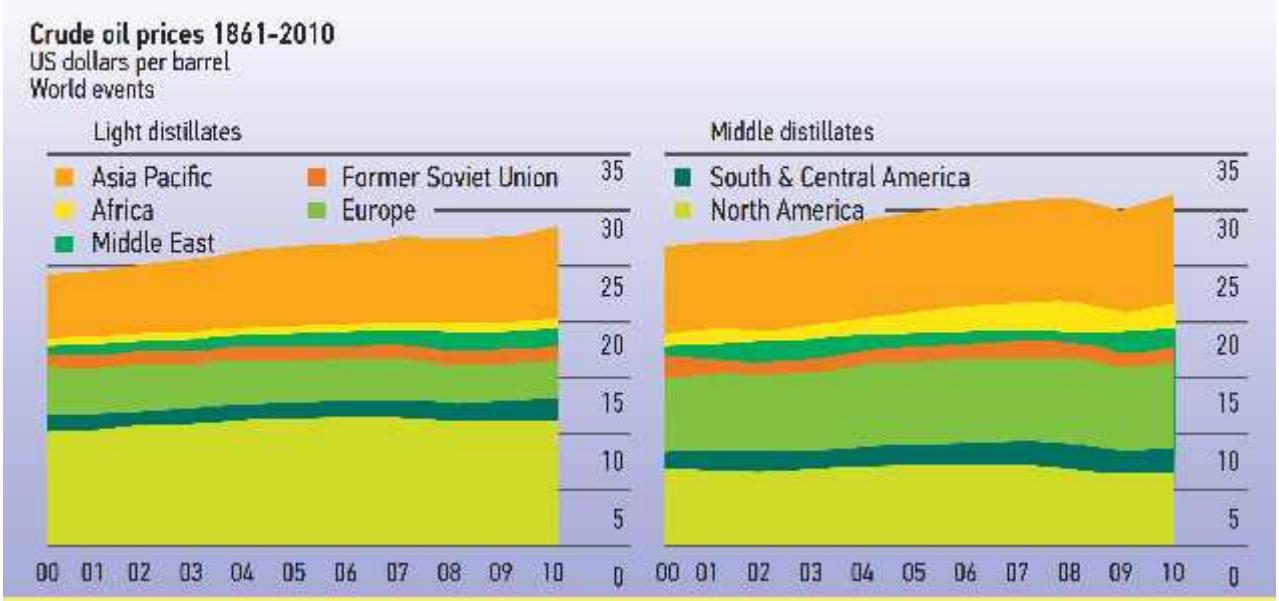


Figure 20 *Products consumption by region*

the first time since 1982, falling in all regions but the The Middle East and Africa. In 2010 consumption increased in all regions.

European Union and Latin America have surplus of gasoline while North America and The Middle East have shortage of gasoline.

The Middle East, Russia, and Latin America have surplus of gas oils, while European Union and North America have shortages.

Russia, Latin America, The Middle East, and Africa have surplus of fuel oil, while European Union, North America, and Asia have shortages.

Figure 21 shows fuel oil and others products consumption by region.

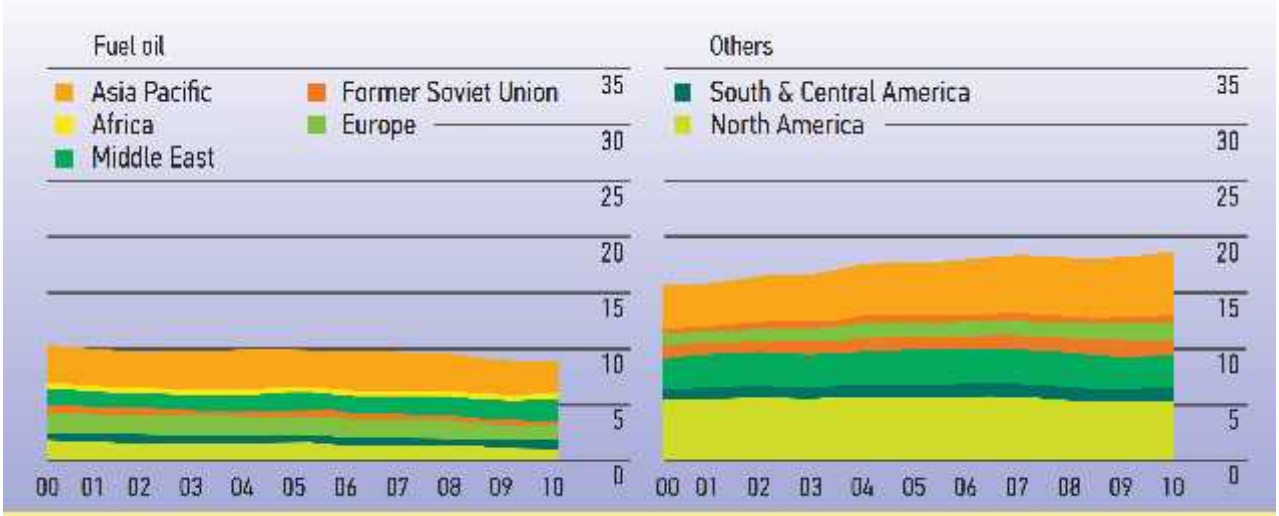


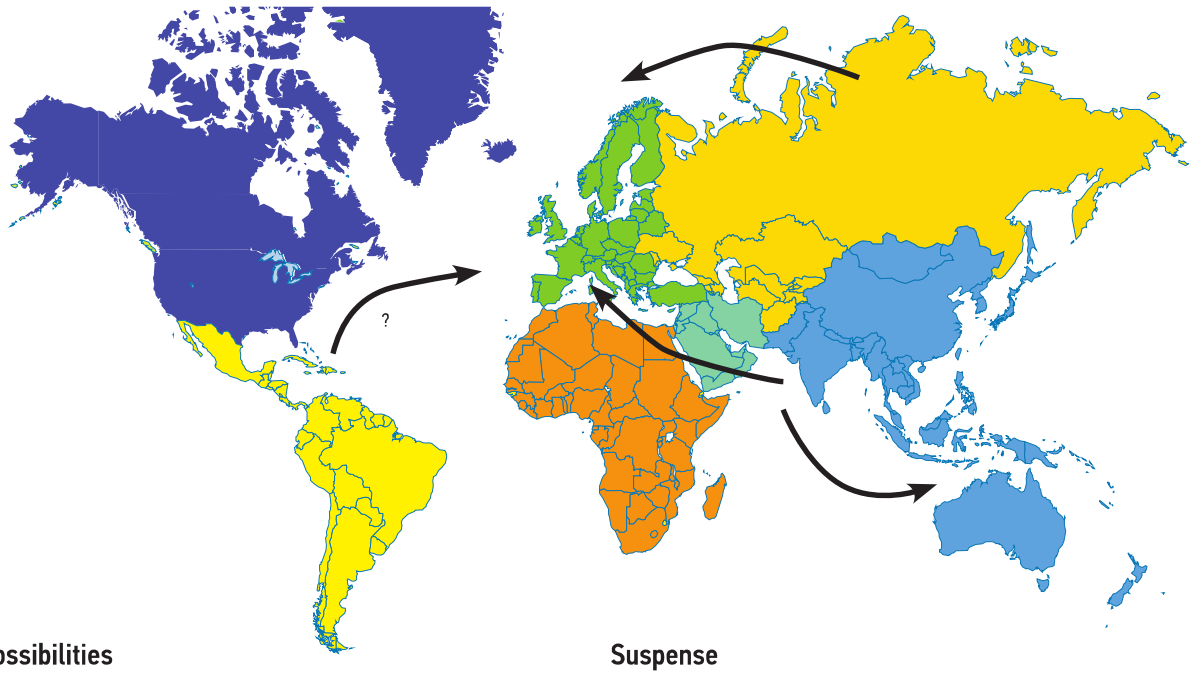
Figure 21 *Fuel oil and other products consumption by region*

Fuel oil consumption experienced the largest decline since 1985.

Future global balance of gasoline and diesel fuel by regions will depend on:

Atlantic Basin gasoline balance	• The issue will be the strength of US demand growth in relation to the surplus in Europe... • ...and the ability of Latin America to meet future US gasoline specifications
Europe/Russia gasoil/diesel balance	• The issue will be the ability of Russia to continue to be able to provide sufficient supply to Europe • ...given the investment required in refining upgrades and logistics • The gap will need to be made up from the Middle East, if US diesel demand growth remains strong
Asia/Middle East gasoil/diesel balance	• The issue will be the amount of refining investment that takes place in Asia and the resulting size of the gasoil/diesel deficit • This situation is interrelated with the Europe/Russia since the Middle East will provide barrels to both regions

Potential global courses of gas oils beyond 2011 are shown in figure 22.



Possibilities
- Possible import in Europe from Latin America
- Middle East and India will be swing producers
- Great important Singapore refineries

Suspense
- Time and level of investment in Middle East refineries
- China balance possibilities/demands
- New approach to European refineries

Figure 22 *Potential global courses of gas oils beyond 2011*

Considering that Latin America has surplus in gas oils, there is a possibility of export to the European Union if its quality is acceptable.

The Middle East will also partially export gas oils to Europe, especially considering the construction of new refining capacities in Saudi Arabia and Iran, if they are completed in planned timeframe.

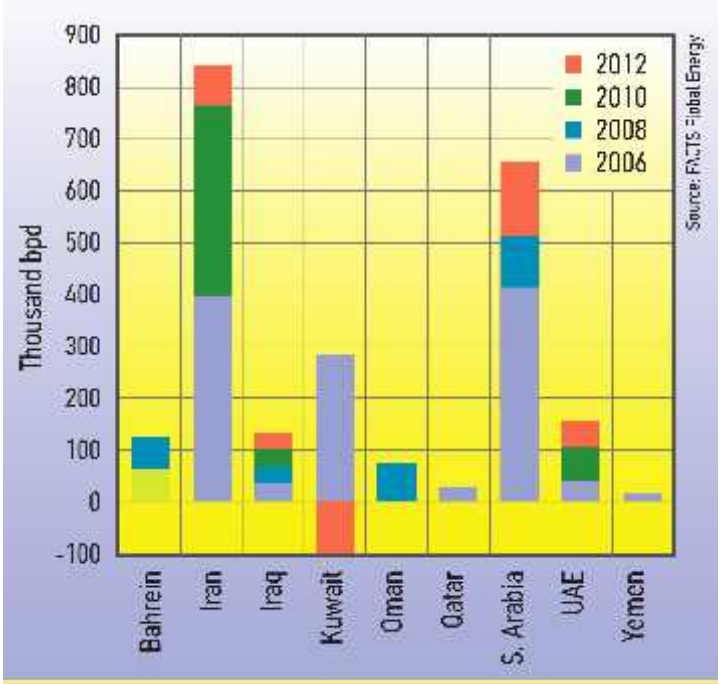


Figure 23 *Dynamics of construction of refinery capacities in the the Middle East*

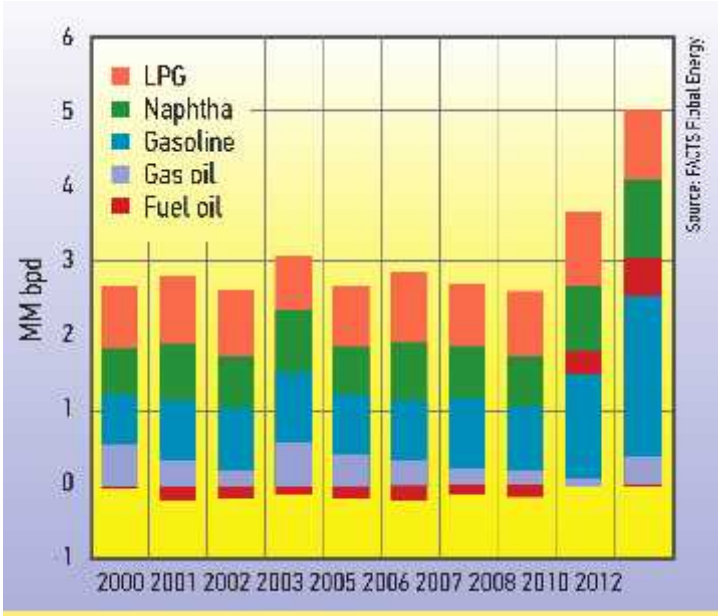


Figure 24 *Future exports of derivatives from the the Middle East*

Supply dynamics of Europe with gas oils will depend on the speed of construction of hydrocracking facilities in Europe.

Large American refineries in Singapore will, due to their technology and location, have important role in supply.

India will after construction of new refineries take over supply of China and other Asian countries.

Expected dynamics of construction of refinery capacities in the the Middle East is shown in figure 23.

It is evident that by 2012 Iranian refinery capacities will increase by 40 million t/y, while in Saudi Arabia by 33 million tons. This means that in the future these countries will export less oil and more derivatives. After 2012, export of derivatives from the the Middle East countries will amount to about 25 million t/y (figure 24).

Figure 24 shows future export of products from the the Middle East.

1.13. Quality of products

Development of automobile engines and installation of catalytic converters for reducing toxicity of exhaust gases influenced quality of motor gasoline and diesel fuel.

Strict environmental protection standards resulted in lower sulphur content in fuel oil and decrease of other harmful compounds that end up in the atmosphere (CO_2, NO_X, SO_2, particles, etc.)

Fuel quality has been changing since first crude oil shock. Critical parameters of fuel quality that have been changing:

- Lead content in motor gasoline,
- Benzene and total aromatics content in motor gasoline.
- Sulphur content in motor gasoline, diesel fuel, and fuel oil.

By year 1973, lead content in motor gasoline was 0.8 g/l, while sulphur, benzene, and other aromatics content were not limited.

Maximum sulphur content for diesel fuel was 1.0% w/w, and for fuel oil maximum was 4.0% w/w.

Development of fuel quality in European Union is shown in Tables 6, 7, and 8.

Table 6 Development of motor gasoline quality in EU

Properties	1978.	1985.	1993.	2000.	2005.	2009.
Lead, g/l	0.40	0.15	0.013	0	0	0
Sulphur, ppm	-	-	-	< 150	< 50	< 10
Benzene, % vol.	5.0	5.0	5.0	< 1.0	< 1.0	1.0
Aromates, % vol.	-	-	-	< 42	< 35	< 35
Olefins, % vol.	-	-	-	< 18	< 18	< 18
Oxygen, % vol.	-	-	-	< 2.7	< 2.7	< 2.7

Table 7 Development of diesel fuel quality in EU

Properties	1993	1996	2000	2005	2009
Density kg/l	0.860	0.860	0.845	0.845	0.854
Sulphur, ppm	< 2000	< 500	< 350	< 50	< 10
Polyaromates, % w/w.	-	-	11	11	8

Table 8 General specification for fuel oil quality

Usage	Sulphur content (% w/w)
General usage	1%
Installed power of load appliance:	No limits (except for SO_2)
> 50 MW	1700 mg/Nm^3
> 500 MW	400 mg/Nm^3
Internal consumption in refineries	No limits (except for SO_2) 1700 mg/Nm^3
For cement industry	No limits

It is evident that in year 2000 production and consumption of motor gasoline containing lead was prohibited in European Union. Italy, Portugal, and Greece were the only countries that got extension until 01.01.2003, allowing them to produce motor gasoline with lead content of 0.15 g/l. Sulphur and benzene content significantly decreased which lead to tremendous financial investments in hydrodesulphurization, hydrocracking and benzene separation processes. Those investments are estimated at approximately 20 billion USD.

Although entering into force on 01.01. 2009. that stipulates maximum allowed sulphur content in motor gasoline to be 10 ppm, some countries of European Union (Germany, Sweden, Great Britain, and Netherlands) have been producing such gasoline with governmental incentive since 2005. These incentives are 1.5-5.0 cents/liter of fuel, which stimulates conversion to better fuel quality. Same applies to diesel fuel.

It is evident that sulphur content radically decrease from 1993 to 2005, due to significant investment in hydrodesulphurization and hydrocracking processes.

For quality of fuel oil, sulphur content is the most important parameter, although some countries and consumers limit metal content as well (Ni + V).

Some consumers such as district heating plants and coal power plants eliminate sulphur from flue gases, so they can use fuel oils with high sulphur content. Because of this, fuel oil quality is specified in particular by emission of sulphur compounds from stationary sources in atmosphere, and it is regulated by EU directive *No. 32/99*, which went into effect 1st of January 2003.

By year 2003, sulphur content in fuel oil that was used by consumers that did not eliminate sulphur from flue gases, was 3.0 % w/w and after elimination 1.0 % w/w.

1.14. Protection of environment

After ecological catastrophes, such as sinking of Amoco Cadiz tanker ship in 1978 and sinking of Exxon Valdez tanker, Chernobyl catastrophe in 1985, Iraq attack on Kuwaiti oil fields, Mexican gulf catastrophe (BP platform), global warming (greenhouse effect) and creation of ozone holes, greater attention was paid to environment protection.

World conferences on this topic were held in Montreal, Kyoto, Rio de Janeiro and Copenhagen resulted in various agreements being signed limiting emissions of toxic substances in the environment. Predicted is further reduction in CO_2, which is the cause of greenhouse effect, NO_X, SO_2 which cause acidic rains, as well as prohibition on use of Freon and other gasses which cause ozone holes. All this is affecting the development of refineries because they not only produce, but they also consume fuels (gas and fuel oil) in their processing furnaces. It is attempted to increase the efficiency of furnaces in order to reduce fuel consumption, thus reducing the emissions of CO_2, SO_2, and with the installation of appropriate burners inside the furnaces reduces emissions of NO_x as well. With the installation of equipment for waste water treatment, it is attempted to meet prescribed quality. Maximum reduction of sulphur contents and other toxic compounds in oil derivatives is continued contribution to protection of environment on local and global levels. Campaign for environment protection and preservation of planet Earth is primary duty of the humanity.