Oil knowledge

What is it?

Oil is a fossil fuel, just like coal and natural gas. Such fuels derive from the rests of plants and animals which died hundreds of million years ago, when mankind had not yet appeared on Earth. Those plants and animals, as it happens today, have accumulated the energy coming from the Sun and, after their death, have remained buried for millions of years until they have turned into oil and coal. Prehistoric animals and plants today return the solar energy they accumulated in the past as heat and electric energy. Great part of the energy we use today comes from fossil fuels, especially oil. However, it is a non-renewable energy source which is bound to depletion sooner or later.
More specifically, oil is a natural mixture of liquid hydrocarbons and other substances of fossil origin contained in sedimentary rocks and associated to smaller quantities of gaseous (natural gas) and solid (bitumen) hydrocarbons.
All the molecules of the existing hydrocarbons include two types of atoms only: carbon and hydrogen atoms. According to the quantity of carbon atoms included in the molecule, hydrocarbons can be in gaseous (up to 4 atoms), liquid (from 5 to 16 atoms) or solid state (over 16 atoms).

Origins of oil

The most favourable environment for the formation of new hydrocarbons includes areas marked by a limited circulation at the bottom and constant accumulation of debris by rivers (ancient seas or lakes), as well as sedimentary basins where the Earth's crust is lowered gradually or quickly following natural geological processes (see image).
Those areas are inhabited by numerous organisms which, when they die, lye at the bottom and are constantly covered by the debris (soil and minerals). The layers of mud rich in organic substances (mother-rock) slowly sink owing to the pressure of new layers. At a given depth and temperature the organic substance "ripens", at first turning into "Kerogen" (approximately 1000 metres and 50°C), then into actual hydrocarbons. The length of the process ranges from 10 to 100 million years according to the temperature.
If the organic substances are abundant, remarkable fields of coal and natural gas can result. If the kerogen does not ripen, and its concentration exceeds 8%, liquid oil can be obtained by heating it artificially. At greater depth methane and light hydrocarbons are produced. Several kilometres away from the surface and at a temperature ranging from 150 to 200°C, kerogen turns into pure crystal carbon (graphite).

Oil fields

Once it has formed, oil is squeezed out of the mother rock (compressed by the layers lying on top) and it first moves through the microfractures (primary migration) and then into the small channels in the permeable adjacent rocks (secondary migration). In some cases hydrocarbons reach the earth's surface and disperse. In others, their migration is blocked by impermeable rocks. In this case the hydrocarbons are trapped and they accumulate. An accumulation of hydrocarbons, in a quantity that can be exploited economically is known as a field.
A trap consists of two elements: below, a reservoir rock that holds the petroleum and above, a cap rock that forms a barrier. Cap rocks are convex on the upper side and are impermeable, so that they prevent the hydrocarbons from escaping. On the contrary the reservoir rocks must be permeable and porous like sponges in order to enable the hydrocarbons to move within, and to make the extraction procedures easy. The size of a deposit depends on the amount of the original reserve – from the over 11 billion tons in the Ghawar deposit (Saudi Arabia) to a few hundred tons in the smaller fields.

What is for?

Many products can be obtained from oil, ranging from some of the most common fuels (petrol, gas-oil and other by-products of oil) to many of the plastic materials used by mankind. The simple hydrocarbons that compose oil are, in fact,

the main raw materials needed to produce plastic materials with specific features: resilience, plasticity, hardness, flexibility, biodegradability, sturdiness, adherence, water-proof characteristics, malleability, etc.
The four most commonly used hydrocarbons are ethylene, propylene, butadiene and benzene. Their molecules make them particularly suitable for composing long organized chains. The complex nature of petrochemical substances is reconstructed through numerous passages and different production processes to achieve a very wide range of products.
Ethylene is the raw material most widely used in the world (5 million tonnes per year). It is used alone to make fruit ripen more quickly and produce detergent marked by a limited foam production.
Polymerization leads to polythene (PE), contained in numerous packages, prints, and linings. The combination of ethylene with water leads to the creation of ethylic alcohol, a solvent for perfumes, cosmetic products, varnish, soap, dyes, textiles and plastic products.
The combination of ethylene and benzene leads to polystyrene (PS), an insulating material used in the building industry and as a raw material to package fragile things and toys. The combination with chlorine leads to polyvinyl chloride (PVC), a widely used material in the building sector and to manufacture waterproof textiles.
Propylene is the starting point of numerous chemical products, including isoprene, glycerine and acetone. The mutual combination of thousands of propylene molecules leads to polypropylene (PP), an ideal substance to manufacture packages and other resilient products. Butadiene is especially used to treat synthetic rubber, leather succedaneum and as solvent.
Finally, benzene, is the starting point to obtain important by-products, such as phenol, aniline, styrene and chlorobenzene, all used in dyes, fibres, resins, plastic, synthetic rubber, pharmaceuticals, insecticides, detergents, textiles. Oil by-products are used as fuels in thermoelectric plants for the production of electric energy, as well as for household heating and the production of hot water.

The reserves

In 2012 oil production covers approximately 31.4% of the world energy consumption (the percentage increases to 52.7% if natural gas is considered). The reserves of that energy source are not distributed in a uniform way in the world; on the contrary, they concentrate in some countries: the Middle East alone has 48%, South and Central America has 20% (Venezuela has 18% of the world oil reserves), North America has 13%, Russia and Central Asia has 7%, Africa has 8%, Asia-Pacific has 3% and Europe only 1%. The comparison between the annual oil production levels and the currently identified reserves shows that Middle East countries produce little as compared to their capacity, whereas the United States and Western Europe exploit their reserves at a fast pace. In fact, the countries that consume more oil are the ones that own less oil. Europe each year consumes 16% of the world production. This means that if the current production level remains unchanged and no new discoveries are made, Europe and North America will deplete their reserves in a few years and will be forced to resort to imported oil only. The reserves identified so far worldwide will be depleted in 52 years if the current annual consumption levels are maintained. The age of oil is probably bound to last for several years still. However, the level of the world energy consumption is expected to grow in the future (the world population will grow as well as the per capita energy consumption), thus reducing the oil reserves at a faster pace than now. The possibility of avoiding new oil and energy crises (i.e. a situation marked by a limited quantity of oil available on the market to meet an increasing demand leading prices to soar) in the future will depend upon the oil industry’s ability to find new fields and above all on mankind’s ability to achieve an optimum exploitation of the currently available oil and develop alternative, possibly renewable, energy sources.
(*Source: eni, World Oil & Gas Review 2014*)

A bit of history

For thousands of years, hunting and collecting vegetables were the main resources of mankind. Human beings could only consume energy, since they were unable to produce it.

Approximately 7000 years ago, mankind discovered agriculture and eventually learned how to produce energy: it was food and muscle energy (produced by human beings and animals helping them), wind and water power (wind and water mills). Crafts, trade, transports were developed along with the exploitation of slaves, a new labour source to support economic development.
The first contact between mankind and oil dates back to that period of history. Oil rarely emerges on the earth's surface spontaneously: 5000 years ago Egyptians discovered its therapeutic virtues and used it to treat rheumatisms and circulation disorders, and to foster the conservation process of corpses (mummification). On the other hand, Persians and Romans used oil for illumination purposes and to manufacture firebombs. However, the use of oil remained episodic for many centuries and played a minor economic role.
During the 17th century England went through en energy crisis owing to the excessive exploitation of wood as fuel and the price growth ensuing therefrom. Thus the energy potential of pit coal – in which England was rich - was discovered. The "Industrial Revolution" started in 1709, when Abraham Darby used pit coal instead of charcoal for the first time. After a little longer than a century, pit coal became the most widely used energy source and new technologies simplified its extraction. .
History speeded up. Starting from the second half of the 19th century, mankind started exploiting new resources: oil, natural gas, waterpower and atomic energy.
The discovery of new energy resources accompanied the population growth and economic development.
Over thousands of years mankind lived off hunting and collecting the fruits of the Earth, almost exclusively using the energy of muscles: under those circumstances the planet could only support a population of 20 millions approximately. With the development of agriculture and the discovery of new energy sources, the population grew rapidly. 16 centuries were necessary to reach the figure of 500 million inhabitants, but only two centuries (1600-1830) to reach the first billion. At present the world population amounts to approximately 6 billions, and hydrocarbons, together with the development of the electric energy, provided a vital contribution to the development of human civilisation during the 20th century, and will continue doing so during the 21st century. However, the other side of the coin is inevitable: the large production of pollution and waste and the growing gap in terms of available raw materials and energy between the Northern and the Southern hemispheres. Only during the last decades of the 20th century did mankind start caring for the planet's health, endeavouring to minimise the impact of its presence on Earth. As regards the gap between North and South, the Governments of the world will need to endeavour very hard to find a solution for a very difficult problem.

Oil fields distribution

When analyzing the list of major producers of hydrocarbons in the world, the differences in the various countries are immediately highlighted. However it must be borne in mind that production is influenced by a vast series of factors, among which the potential of the reserves is only one of the main ones; technical factors can make extraction more or less difficult even in the presence of large reserves and economic factors may lead to an increase in the production depending on the demand. For example, the production of the USA is very high compared to the estimated reserves, while in the Middle East, which has enormous reserves, the production/reserves ratio is very low. Therefore it is important not to confuse production with the size of the reserves. The largest producers are not necessarily the countries with the largest reserves. 48% of the oil reserves is localized in the Middle East. Most of the oil reserves are in Veneziela, accounting for 18%; the countries that follow are Saudi Arabia, Canada, Iran, Iraq, Kwait, United Arab Emirates, Russia, Libya and Nigeria. Most of the gas reserves, instead, are in Rusia, accounting for 24% of the world reserves, followed by the Middle East, Iran and Qatar, which together account for 29% of the total.

Giants in the world

The reserves are classified according to their size and the amount of hydrocarbons they contain, in millions of barrels (for oil) or billions of m3 (for gas), according to a classification made by API (American Petroleum Institute). Till date, in the world, 2 megagiant, 40 supergiant and 330 giant reserves have been discovered. The largest reserve is the Ghawar megagiant field in Saudi Arabia (83 billion barrels), followed by Greater Burgan in Kuwait (70 billion barrels) and by Costanero Bolivar in Venezuela. Out of the 20 largest oil and gas reserves in the world, 15 are in the Middle East (6 in

Saudi Arabia, 4 in Iran, 3 in Iraq , 1 in Kuwait, 1 in Abu Dhabi), 2 in Russia, 1 in South America (Venezuela) and 2 in North America (1 in USA-Alaska, 1 in Mexico). Out of the 20 most important gas reserves, 12 are in countries of the former Soviet Union, 7 in the Middle East and 1 in North Africa (Algeria).
(*Source: eni, World Oil & Gas Review 2014 and "Enciclopedia degli idrocarburi"*)

Oil fields in the world

The distribution of the principal oil fields in the world is not uniform, but neither is it random, and it depends on particular geological conditions that are necessary for the formation of large reserves and the difficulty of exploring and researching oil in isolated areas that are not well known, such as areas characterized by particularly severe environmental conditions (the vast areas of Siberia, the areas of the rain forest in South America and the deep offshore areas). The more important oil fields have geological characteristics that are very different from each other, but they have some common elements. According to the above stated considerations, the first areas in which to search for hydrocarbons are the areas in which sea sediments are present, where the seas are not very deep and are rich in organic substances developing in anoxic environments, which are the ideal mother rocks for hydrocarbons. These conditions are to be found in the fields that are near to stable continental areas (the so-called cratons), where detritus sediments coming from the emerged lands form powerful and thick deposits of permeable material (reservoir rock) covered with fine marine deposits (cap rock). For this reason, many of the more productive fields are to be found along the borders of the continents: in the North American fields in Texas and Louisiana, in the Gulf of Mexico, in the Mexican fields in Tampico-Misantla and Sureste, in the Central African fields of the Niger delta and the Congo Basin and the enormous fields in Western Siberia.
Similar situations with longer, narrower fields also form in the rifts along the borders of subduction areas. In these areas the tectonic deformations can create efficacious structural traps, as in the Venezuelan fields along the Andes mountain range or as in the Sumatra field. Also deep fields characterized by a rapid sedimentation are favourable regions for the formation of important reserves, as for example in Europe in the small province of the Rhine basin or in Graben in the North Sea, that are the most important reserves in Western Europe. Also the large Sirte field in Libya has a similar origin. However, it is in the continental collision areas, that lead to the formation of mountain ranges, that the more favourable situations for the formation of numerous and important structural traps are generally found. In these areas the reserves are very often numerous and their volume is large. The enormous oil fields in the Middle East, that are the most extensive and important in the world, follow the trend of the mountain ranges that were formed from the collision of the Euro-Asiatic plate and the Arabian plate.
Also the large fields of the Volga and the Urals, are in a continental suture area, but they belong to a more ancient orogenetic cycle. The collision of the African plate and the European plate in the Mediterranean area, created numerous mountain ranges, among which the Pyrenees, the Alps and the North-African ranges. Near these areas, in particular in the accumulation reservoirs on the front of the mountain range, we find the largest Mediterranean oil fields, such as the Sahara field, but also the largest Italian oil provinces (such as the Po valley, the Adriatic coast, South East Sicily and the Sicily Channel).Important reserves are also to be found, all over the world, in areas where the presence of levels of evaporitic rocks has led to the formation of diapiric salt as for example in many reserves in Central Europe and in the area around the Gulf of Mexico.

Hydrocarbons in Italy

The geology of our country (Italy) is very complex and the peninsula consequently has a complicated sedimentary and structural order, that is not very calm. This has not favoured the formation of large and extensive oil fields, but has created local situations that are favourable for the formation of numerous oil provinces that are reasonably important, even though their extension is not great.
Our country can, from a tectonic point of view, be subdivided into **4 "districts"**. These are all tied to the presence of the mountain ranges of the Alps and Apennines:

- a "rear-arch" field , an area that is not greatly deformed, consisting in the Tyrrhenian Sea;

- a mountain range area, that consists in the big “arch” that stretches from the Alps to the Apennines, and that forms the backbone of the Calabria and Sicily regions;
- a “fore-rift” area, a depressed field that is not greatly deformed, that is located in front of the mountain ranges advancing on the so-called “fore-country”, consisting of the borders of the Adriatic Sea, the Ionian Sea and the Sicily Channel;
- the “fore-country” area, an area that is still not deformed, towards which the mountain ranges that are forming move, which consists in the Po Valley, the Adriatic Sea, South East Sicily and the Sicily Channel.

The most important Italian provinces for oil are the Northern area of the Adriatic Sea, the Po Valley (gas and oil), the Pescara field (oil and gas) the Southern Area of the Adriatic (oil and gas), the Southern Apennines (oil), the Fossa Bradanica in the Puglia region (gas and oil) the off-shore platforms of the Calabria region (gas), Central Sicily (gas) and the Pelagic fields (oil).
The most important oil reserves are in Val d'Agri (Potenza) and Villafortuna-Trecate (Novara). Val d'Agri is the province with the greatest oil reserves in Italy. Hydrocarbons are to be found in the anticline folds of the Mesozoic calcareous areas of the Apulian Platform, covered by the slopes of the Apennines in the Campania and Basilicata regions. The presence of oil and gas on the surface have been reported in Tramutola. These escaped from deeper traps following the tectonic deformations in the Apennine mountain range. In the Villafortuna-Trecate fields, hydrocarbons are in Mesozoic carbonate rocks that were fractured due to the Alpine deformations buried below the Po Valley, with one of the deepest liquid hydrocarbon fields in the world (6,200 m).
The distribution of the principal oil provinces in Italy, clearly reflects the geological situation: the comparison between a structural map of our country and a map of the main fields, in fact, shows that approximately 40% of the reserves are in mountain range areas (like the reserves of the Southern Apennines and Central Sicily), while the remaining 60% are in the fore-rifts and fore-country areas - the reserves in the Northern Adriatic Sea and the Po Valley, closed between the front of the Alps and the front of the Apennines that are moving towards each other; the Pescara field and the Southern Adriatic field are closed between the Apennines; and the Dinaridi around the Dinara Mountain area to the East, and the off-shore platforms of the Calabria region, South-Eastern Sicily and the Sicily Channel. From a simple comparison of the two maps, it is quite easy to see the controlling influence of the geological and structural order of a region on the distribution and importance of the hydrocarbon reserves we may hope to find therein.