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Review

Is the world running out of oil?

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As Mark Twain said, prophecies are always difficult to make, that's why nobody can say precisely how much oil there is in the world and which is yet to be discovered, for how long will last the oil we already know about and where it is, how much will we be able to exploit what we have and what is there to discover, for how long will the oil last, for how long we will need it, if we already went beyond the maximum peak of production and discoveries etc. We can only analyze the data we have, make calculations, predictions and assumptions on the basis of what has been in the past, and what it is in the present, to hope or, on the contrary, to prepare ourselves for the worst. But we can't know for certain. So we try in the following to do it, without claiming that we know the sure answer to the question that is on the lips of all humanity. Further can be found: an analysis on the oil reserves in the world, starting from the reserves discovered and put into service (as they were declared), reserves discovered and unexploited yet, reserves proven, but still undiscovered and forecasts, by the experts in the field with regard to future discoveries.

Keywords: oil, reserves, Peak Oil, Saudi Arabia, giant oilfields

INTRODUCTION

As it is known, energy has an overwhelming importance for all humanity. We live in a world completely dominated by energy, which has become the foundation of wealth, of comfort, and which can be found in almost anything we produce or consume. Everything we buy represents a certain amount of energy, first produced and then consumed. And oil has become the most important global resource, being present in almost all aspects of our everyday living: household products, medicines and medical equipment, consumer goods etc., not to mention the fact that oil also supplies the industry and many of the products available today would no longer be accessible in the absence of oil.

Thus, oil, the main factor of energy, is a part deeply integrated into our culture and has been (still is, as regards the regions under development in the world) the "engine" behind industrialization. There is no country in the world that can isolate itself from the issues existing on the oil market. Oil issues affect each nation in the world, with no exception.

Global oil reserves and the Peak Oil

The history of oil goes a long time ago, being almost as old as the civilization. And nowadays, oil became so tied

to the economic and political spheres that, as Paul Roberts writes, the governments of major industrialized countries keep an eye on the oil market with as much attention with which they once monitored the spread of communism. And this fact is justified and sustained by previous experiences: six of seven global recessions were preceded by sudden increases in oil prices. Moreover, economists and decision-makers fear that in the global economy of today, energy-intensive and dependent on the economic growth, the sudden changes in the oil price could be one of the highest risks to prosperity and stability, probably higher even than terrorism or war. "Energy has become the means of payment of the political and economic power, the value which determines the hierarchy of nations, even a new indicator of success and of material progress." Roberts, *The End of Oil*, 13.

Even since the first probe drilled in 1859 for the first time in an oil field, in the United States, oil has become increasingly a part of our lives, in particular because it has the greatest concentration of energy as compared to any other fossil fuel. Today, oil is the most important asset of modern world and all nations use it, without any exception. We may even say that it is the "engine" of life, as we know it today, and we live in a world that can no longer function without oil. Our dependence on this resource has become so great, that we may say we can no longer live without it. However, to be produced, oil must, in the first place, be discovered. Therefore, when we think about the future production of oil, a very important question that arises is how much raw crude oil there is in the world and which can be produced: what amount has already been discovered and what amount will be discovered in the future.

We know that oil has been formed in unusual circumstances, with more than 500 million years ago. In the year 1859, in the America of the 33 states, Edwin Drake drilled the first oil well in Titusville, Pennsylvania. Drake's discovery kicked off the period called the "The Oil Era", whose end is not far away, according to the speculations of some researchers in this area. Since that year, oil has become the foundation of development and evolution and a source of enrichment for the nations that "control" this resource. The amount of oil remaining in the world is not yet known, although assumed, but the competition for the control of reserves in the Middle East and the fear as regards their future were reasons even for war (Greene, 2010).

When talking about the oil reserves, the main attention is, of course, directed over the OPEC states, especially because in their case there are the greatest doubts as regards the veracity of the publicly reported data with regard to the reserves owned, and, in particular, to the "giant" oilfields, because these are the ones which currently ensure the largest part of the amount of oil used today. In the context of this brief analysis, Saudi Arabia is the one which came most "under scrutiny", being the

State with the most important oil reserves, with the largest production and with the highest exports between the producing states.

That the world will run out of oil, probably somewhere in the near future, seems obvious to some specialists in the field; as a matter of fact, there is a finite amount of oil on Earth, and this does not leave room for discussion. And logic tells us that, since oil is a finite resource, the offer will diminish rapidly in the presence of a growing demand, and the days in which we "bathe" in oil are soon coming to an end. But the idea that oil is a finite resource means that there is a moment in which the oil consumption has begun and there will be a time when it will cease. Between the two moments, there is a period in which oil is produced at a maximum rate, known in the literature under the name of "Peak Oil" or "Hubbert's Peak".

Because oil is one of the most important natural resources of our days, oil companies in the world, which aim at obtaining maximum profits, are all the more advantaged as the information about oil are more limited, so as to allow speculation and thus to increase the value (and thus the price) of the resource that ensures they can operate. Information on oil stocks remained in the world, their rate of production and consumption, as well as predictions with respect to the future of this resource are provided only by a small number of organizations and companies, state-owned or private. There are associations which deal with informing the general public on the reserves and production of oil, associations such as Energy Information Administration - EIA - in the United States, or International Energy Association - IEA - in Paris, but there are suspicions that the information submitted by these are based on political considerations, not just natural, and sometimes the information transmitted are influenced by political decisions. Data with respect to oil and everything that is related to it are very hard to find, the vast majority will be kept confidential, and, in the case of those that are not hidden - are often very expensive to purchase, or very old. Moreover, most of the time, the information provided (not only the public, but even the official and those used in national and international reports or operated only in the oil industry) are not always reliable, and there are always suspicions regarding them (especially when it comes to the data in the Middle East). This is why complex analyzes that appear on the market and which are intended for the general public are, most of the times, staggered and contain information relating to data dating 4-5 years back and sometimes even more, which may distort the analyses and conclusions at a certain point in time.

For the most part, the oil (which can be extracted, for there are also oilfields that can not yet be extracted with the currently known means) has been discovered between 1945 and 1970. We already know where we can find on Earth new oilfields, but the amount which these

can produce will be limited as compared to that of the oilfields already discovered. Also, we know that the big oil companies have made the most important discoveries of oil in the 1960s. The average size of the oil fields discovered since then until now declined every decade. And this trend is an argument strong enough to estimate how much oil can be found further on, in the absence of concrete information about what there is, and will be in the future. Moreover, we all know that there are limits to how much oil can be produced every year. All of this, together with the fact that the oil production from the largest reserves begins to decrease, may mean that the hopes of oil companies and of national and international agencies for an increased oil production are only hopes without a realistic foundation.

An important source of information is the EIA (U.S. Energy Information Administration), one of the most quoted sources from the literature on the subject, and the statistics reported by EIA with regard to the international reserves of oil are compiled in the publication *Oil and Gas Journal*. The figure below shows the reserves at the end of 2008 in relation to world regions, as published in the *Oil and Gas Journal*. Global reserves at the end of the year 2008 were of 1.34 trillion barrels (without the liquefied natural gas), and at the

production rate of 2008 these reserves were considered to be sufficient for approximately 50 years.

Five years later, in the publication *BP Statistical Review of World Energy* (another important source of information with respect to oil) from June 2013, the reserves discovered at the end of the year 2012 have been valued at approximately 1,669 billion barrels, including raw crude oil and liquefied natural gas. Also, according to the same publication, global production for the years 2010, 2011 and 2012 was as follows: 83.27 million barrels per day (30.39 billion per year) in 2010, 84.21 million barrels per day (30.74 billion barrels per year) in 2011 and 86.15 million barrels per day (31.44 billion barrels per year) in 2012, resulting in a total production for the last three years of 92.57 billion barrels. If we add also these data to those from 2009, it results a total amount of 3.6 trillion barrels, including here also the liquefied natural gas (an increase of 0.1 trillion barrels as compared to 2009).

If we assume that indeed the total amount of oil is a stable number around 3.6 trillion barrels, what does that mean in terms of global exhaustion? As a crude and simplistic method, we can estimate that the remaining oil is to be consumed on the basis of the consumption rates in the past few years. Since one-third of the total amount of oil has already been consumed, there remain approximately 2.4 trillion barrels to be consumed as of 2013. According to EIA, the global oil production was in 2012 about 89.31 million barrels/day, i.e. 32.6 billion barrels per year. At this rate of production, the remaining 2.4 trillion barrels will end in only 71 years, i.e. in 2085 (2.4 trillion barrels divided by 32.6 billion barrels per year). According to *BP Statistical Review of World*

Energy, the June 2013 edition, taking into account the world reserves at the end of the year 2012, of 1,668.9 billion barrels, as well as the rate of production calculated by BP at the level of 2012, it is presumed that such reserves will be sufficient for almost 51 years. Taking into account the above values for the total amount of oil and production, it took us about 100 years to exhaust the first third of the total oil amount, and it may take us less than 100 years to consume the remaining two thirds. However, if the global production rate would be twice as high as that in 2012 (a pessimistic scenario, but not very difficult to believe, considering the demographic growth and industrial development of China and India) and not at the same level, as we have assumed above, then the exhaustion of 2.4 trillion barrels will be done in 38 years. However, it is unlikely that the rate of production increases so much in the next few years, considering that, for example, its growth in 2012 as compared to 2011 was just of 2.2 %.

But what degree of confidence can we have as regards the above data or others, made available to the public and made available to all? Especially as regards the ones in Middle East? For example, at the end of the 1980s, the declared reserves of OPEC Member States have increased dramatically. During the 1970s, the most influential members of the OPEC cartel have expropriated the assets of international oil companies and have transferred them to the national oil companies. Then, in 1985, Kuwait has reported reserves with 40% higher than those previously reported (Alekkett and Campbell, 2003). The motivation behind this increase consists in the OPEC method of determining what volume of oil the member states are allowed to produce: the production volumes shall be determined in proportion to the size of the oil reserves of a member state. When Kuwait has increased its declared reserves, was thus able to increase its production rate at the expense of other OPEC member countries. Three years later, Venezuela, a member of OPEC, has doubled its reserves by including in its declared reserves also the black oil from the Orinocco Belt, that had not been included previously (Alekkett and Campbell, 2003). In response, the other OPEC states have increased their reserves by the following amounts: Abu Dhabi with 197%, Dubai with 186%, Iran with 90%, Iraq with 112% and, in the end, Saudi Arabia with 51%. Between Kuwait and Saudi Arabia there is an area called "neutral zone", which is administered jointly by both countries. For that area, however, has not been declared any increase (Alekkett and Campbell, 2003). Going further: in 1984, OPEC members in the Middle East have reported reserves of 357 Gb, but, until 1990, the reported reserves increased to 644 GB, which means a growth of 80%. During this period, there has not been reported any "giant" oilfield discovery, despite the fact that many such discoveries should have had to reflect such an increase in reserves. Until 2009, OPEC members in the Middle East have

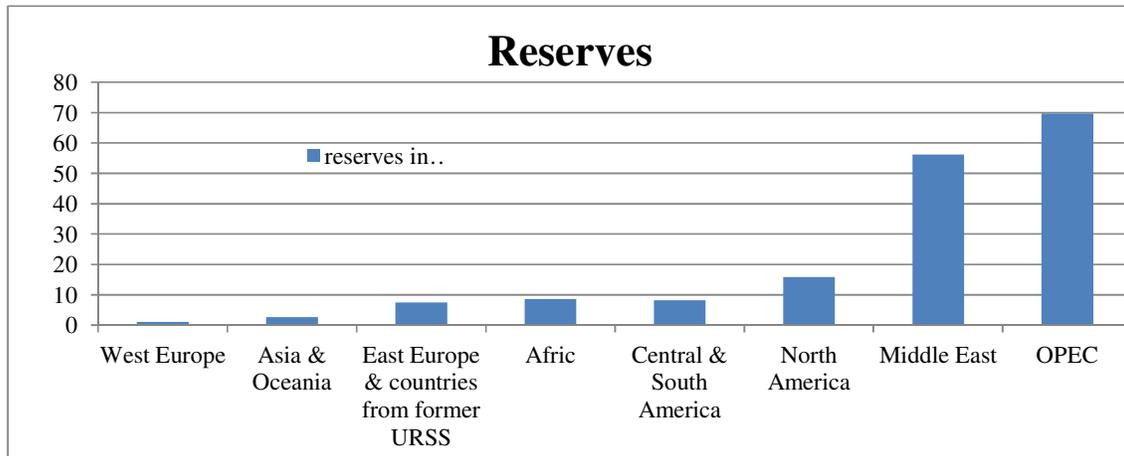


Figure 1 Regional percentages of global oil reserves at the end of year 2008. OPEC holded, in 2008, 70% of the global reserves (source: EIA - *Oil and Gas Journal*)

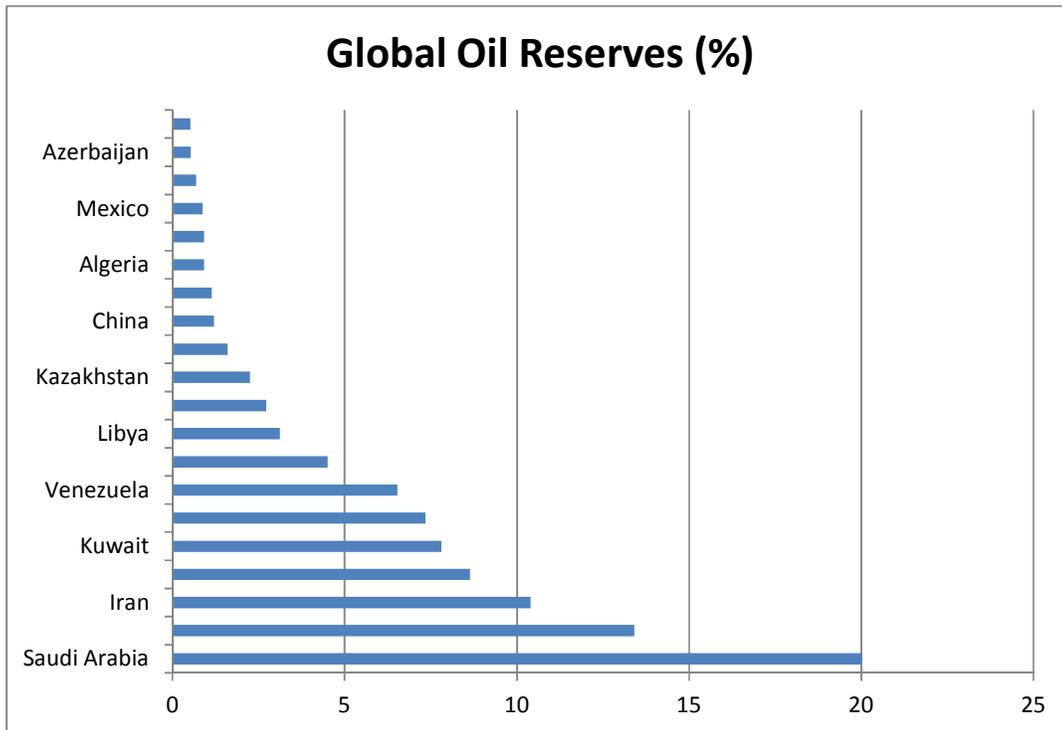


Figure 2 Oil reserves of 20 countries, counting 95% of the total global amount in 2008 (source: EIA - *Oil and Gas Journal*).

reported an increase in reserves to 716 Gb, and in 2012 the reserves declared have been of 1,211.9 Gb. During this time, over the last 20 years, these countries have produced 182 Gb. The question is now how big really are the remaining OPEC reserves. In 2012, they have produced a total of 13.65 Gb (*BP Statistical Review of World Energy, June 2013*), which would mean

approximately 1% of their reserves reported in that year and approximately 3% if their reserves are in fact of 400 GB. Compared to the North Sea, where owners have a production of 6% per year, the figure of 1% is unrealistically low. If, instead, the countries in the Middle East, members of OPEC, have a production of 3% per year, it would still mean that Middle East is the area with

Table 1. The biggest 21 oil reserves of the world according the remaining reserves measured in billion barrels (Gb) (BP Statistical Review of World Energy, 2013).

| Reserve's name | State | Discovery year | Year of starting the production | Interval of remaining reserves (Gb) |
|----------------|--------------|----------------|---------------------------------|-------------------------------------|
| Ghawar | Saudi Arabia | 1948 | 1951 | 66-150 |
| Greater Burgan | Kuweit | 1938 | 1945 | 32-75 |
| Safaniya | Saudi Arabia | 1951 | 1957 | 21-55 |
| N & S Rumaila | Iraq | 1953 | 1955 | 19-30 |
| Bolivar | Venezuela | 1917 | 1917 | 14-30 |
| Samotlor | Russia | 1961 | 1964 | 28 |
| Kirkuk | Iraq | 1927 | 1934 | 15-25 |
| Berri | Saudi Arabia | 1964 | 1967 | 10-25 |
| Manifa | Saudi Arabia | 1957 | 1964 | 11-23 |
| Shaybah | Saudi Arabia | 1968 | 1998 | 7-22 |
| Zakum | Abu Dhabi | 1964 | 1967 | 17-21 |
| Cantarell | Mexico | 1976 | 1979 | 11-20 |
| Zuluf | Saudi Arabia | 1965 | 1973 | 11-20 |
| Abqaiq | Saudi Arabia | 1941 | 1946 | 13-19 |
| East Baghdad | Iraq | 1979 | 1989 | 11-19 |
| Daqing | China | 1959 | 1962 | 13-18 |
| Romashkino | Russia | 1948 | 1949 | 17 |
| Khurais | Saudi Arabia | 1957 | 1963 | 13-19 |
| Ashwaz | Iran | 1958 | 1959 | 13-15 |
| Gasharan | Iran | 1928 | 1939 | 13-14 |
| Prudhoe Bay | USA | 1968 | 1977 | 11-14 |

the largest reserves of raw crude oil in the world.

Saudi Arabia

Saudi Arabia has been, is and probably will remain for a long time the most debated and analyzed state when it comes to oil. And with good reason, considering that it is the state with the largest world reserve and with the most giant fields. In 2004, there were 85 oilfields in Saudi Arabia, composed of 320 small tanks. In 2004, official information (information provided by Saudi Aramco, the national oil company of Saudi Arabia) showed that the oil production of Saudi Arabia was of 10 million barrels per day, which sum up 3.65 billion barrels per year. According to the information made public, each year the oil produced by Saudi Arabia is replaced by new reserves. Also, in 2004, this State has publicly declared that they had discovered 700 billion barrels of oil in total and that, in 2004, their reserves were of 260 billion barrels. However, in that year, only 131 billion barrels of the reserves were operated and produced oil. At a production rate of 3.65 billion barrels per year, this means that Saudi Arabia was producing approximately 2.8% of the reserves. In the symposium organized by CSIS (Center for Strategic & International Studies) in Washington, in the presentation of February 24, 2004, Saudi Aramco revealed that they strive to maintain low

production rates in each oil field because this is one of the requirements necessary to ensure high factors of recovery. In the report *World Energy Outlook 2005*, IEA has published a special analysis on the nations in the Middle East and North Africa. From this analysis, Saudi Arabia accounts for a significant part of the report (*World Energy Outlook, 2005*). According to this study, Saudi Arabia had, at that time, approximately 90 known oilfields and approximately 30 of them were in production. 10 of the 30 had proven reserves of 10 billion barrels and even more than that. Worldwide, there are only 30 fields of the same size. It results from the above that one-third of these fields are in Saudi Arabia, which demonstrates how rich in oil this country is. Although it is well-known that, even if there are 30 oilfields exploited in Saudi Arabia, more than 80% of this country's oil is to be found in only 10 fields. Oil production from Saudi Arabia is dependent, therefore, in the future, on these 10 fields (Ghawar, Safaniyah, Manifa, Shaybah, Zuluf, Abqaiq, Berri, Khurais, Marjan and Qatif).

In a presentation dated December 1st, 2007, at a symposium organized by Saudi Aramco (Aramco Drilling Symposium), Abdallah al-Saif, vice-president to Aramco at that time (Aramco Senior Vice President for Exploration & Production), has reported that Aramco owns 716 billion barrels of the total reserves, of which 51% are recoverable. Then he offered promising forecasts - based on the historic evolution - such as that

in 20 years, Aramco will own more than 900 billion barrels of the total reserves and that future technologies will allow a rate of recovery as regards them of 70%. Compared to the information provided in 2004 to CSIS in Washington, it seems that in 2007 Saudi Aramco have not change their point of view on the country's reserves and oil resources (700 billion barrels of oil discovered and 200 billion barrels undiscovered yet). Dr. Sadad al-Husseini (former Vice-President of Manufacturing and Operations at Aramco) agreed with the generally accepted estimate of 360 billion barrels of "proven reserves, oil which has already been produced or which is available for exploitation, based on current technologies". He also talked about the importance of investments in personnel, in infrastructure and management for achieving a production of 12.5 million barrels per day in 2009. However, in 2012, production amounted 11.6 million barrels per day, and the reserves discovered were at the end of the year 2012 of 265.9 billion barrels (BP Statistical Review of World Energy, 2013). But we know now that, as a matter of fact, Saudi Aramco really made the necessary investments, and the period in which the company will be able to obtain production at the level of 12.5 million barrels per day will depend on the extent of future investments. Currently, the goal of Saudi Arabia is no longer to increase oil production, after the target set by Saudi Aramco, of 12 million barrels/day, was reached in 2009. So that the main concerns of this nation are now directed toward natural gas, refineries, petrochemical industry and electricity industry. According to *Oil and Gas Journal*, Saudi Arabia holds discovered reserves of approximately 265 billion barrels (plus 2.5 billion barrels in the neutral zone between Saudi Arabia and Kuwait), at the end of the year 2012.

The giant oilfields

And, for that we have talked about the ten large oilfields of Saudi Arabia, let's look back a little to the largest oilfields of the world. For that, in addition to the global figures and numerical values, it should be considered also the quality of these reserves and the possibility of extracting them. Thus, the oilfields which supposedly contain remaining reserves larger than 500 million barrels are defined as "giant oilfields", and the oil industry gave them the nickname "elephants". From a historical perspective, the giant oilfields have dominated the global oil production, and future production of these oilfields will be essential for our access to oil. For example, Cantarell in Mexico is one of the 10 largest oilfields in the world. This oilfield has passed through all stages of development, and now production has decreased dramatically. Technological interventions can not prevent this decline, therefore Cantarell is heading towards its "last breath". Instead, Ghawar in Saudi Arabia is the

largest oilfield of raw crude oil in the world. This has a length of 280 km and a width of 26 km and can be compared with the highway between Brussels and Paris. Over the past few years, for this field has been reported a stable production of approximately 5 million barrels per day, which is the equivalent of 7% of the total world's production of raw crude oil.

In addition to the production from the "giant" oilfields, oil is also produced from a large number of smaller oilfields (and there are many small oilfields that have already been abandoned). According to the *"Oil & Gas Journal"*, in 2006 in the United States were 34,969 productive oilfields (Radler, 2006), and ISH Energy has stated that, in 2005, outside the United States, there were 12,465 productive oilfields (Chew, 2005). In the last few years, there have also been discovered and/or put into service new oilfields, the total number of productive oilfields exceeding the amount of 47,500. Of these, 507 have been reported to be giant oilfields, which means that approximately 1% of the oilfields are giant.

To highlight the importance of the giant oilfields, if we add the production of the 100 largest oilfields of the world, we will find out that they account for 45% of the total production of raw crude oil. If we add all the oil amount that has been produced and the whole amount of oil which we estimate that we will produce, then the reserves remaining in the giant oilfields represent 65% of the total worldwide. So it is no wonder that throughout the whole twentieth century, the production of the giant oilfields has dominated global production.

It is very difficult (almost impossible) to obtain precise information about the remaining reserves relating to the giant oilfields. For example, if someone gathers information about Ghawar from a varied number of articles and newspapers, may find values about URR ranging between 66 and 150 billion barrels (Robelius, 2007).

As we have seen, giant oilfields in the world are a small part of the total number of oilfields, but their importance is huge. More than 50 % of worldwide production comes from them, and more than half of the worldwide reserves can be found also there. Based on this, it is reasonable to assume that future development of the giant oilfields will have a significant impact on the world oil supply.

In order to better understand the giant oilfields and their future behavior, we have to understand their history (Höök et al., 2009). We can see three phases in the history of giant oilfields: the buildup phase when production increases, the plateau phase when production is relatively constant and the decline phase. Of course, the remaining recoverable resources are dropping constantly during the productive lifetime of the oilfield. This means that, in order to maintain a constant rate of total production during the plateau phase, production rate of the remaining reserves should be in fact increased. A remarkable observation which we can make is that oil production from many giant oilfields starts declining long

before having extracted half of the oil existing in that oilfield. For terrestrial oilfields, the average percentage of URR produced when the production peak occurred is of 34% and for the offshore oilfields is of 44%.

As a general rule, when we ask how much oil there is, we are referring to two different kinds of oil: the undiscovered and the discovered, but which is not yet in operation. The latter form, in essence, the inventory of some companies like Exxon Mobil and of some petrostates such as Saudi Arabia or Norway. According to the International Energy Agency, one of the most respected and most quoted oil agencies in the world, world reserves discovered and unexploited are around the figure of 1.7 trillion barrels, of which more than half are located in the Middle East (the evaluation includes approximately a trillion barrels in proved reserves, plus another seven hundred billion barrels in "additional reserves", new oil in essence, which was discovered in the existing fields or even in the abandoned ones). International Energy Agency, World Energy Outlook, 47.

According to the U.S. Geological Survey Agency, the undiscovered oil is somewhere around 900 billion barrels. Totalling the reserves undiscovered with those discovered and unexploited, we get a total of 2.6 trillion barrels. Paul Roberts estimates, on the basis of these data, that reaching the peak will occur around 2030 or even later, if the global consumption rate would decrease. Paul Roberts, 67. The problem is that both figures, both for the oil discovered, as well as the oil undiscovered are questionable.

CONCLUSIONS

Sooner or later, however, we must go back to the fact that a large proportion of the world's oil is located in the Middle East, controlled by OPEC, which already exercises a great control over the oil price on the international market and which will acquire even more power once the oil fields outside OPEC begin to dry out. Thus, although it will be important to know when the total production reaches its peak, for the time being, when governments and oil companies ask questions related to a peak of oil production, what they actually want to know is when the non-OPEC oil reaches its peak.

Oil, like any other fossil fuel, is a finite resource. There is a certain amount of oil available in the world, which is not

renewable, therefore the idea of a shortage of oil makes this resource one extremely valuable, and its offer leads to political conflicts and sometimes, even military.

During the nineteenth century, coal was the most important fuel of humanity. However, oil has started to become more and more important in the 20th century and now, in the 21st century, natural gas is a more and more important source of energy. So that, no matter how unavailable a resource may seem to us in a specific time, there were always and there will always be discovered new sources of energy, which to complement and, eventually, to replace those used and on which the whole civilization seem to rely upon.

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