Energy: An Oil & Gas Primer

Thank you to Swedbank and Kepler Cheuvreux Swedbank for releasing the material

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Mats Larsson, July 24, 2018

Contents

- 7.1 Introduction
- 7.2 History And Geopolitics
- 7.3 What Is Oil?
- 7.4 The Players
- 7.5 The Production Chain
- 7.6 The Oil Price
- 7.7 Gas, Coal and Unconventional
- 7.8 Energy investing

7.1 Introduction

US shale revolution

The US shale revolution is redrawing the energy map of the world. In 2014 the US replaced Saudi Arabia as the world's largest producer of oil. The forecaster of such a development 5 years ago would have been taken away by men in white coats. The US has also overtaken Russia as the world's largest producer of natural gas. This secular growth of this non-OPEC supply source combined with a slowing Chinese demand paved the way for the dramatic falls in oil prices we have seen lately. Notwithstanding all the current drama, mankind's relationship with energy is hardly new.

Growth = energy usage

The raise of the modern world with all its comforts and technologies has been tightly coupled with the increased usage of energy. The correlation between the size of a country's GDP and its usage of energy is very strong and continued future Emerging Market led global economic development will no doubt require a larger energy usage. The primary supplier of energy supporting economic growth during the last 300 years has been the carbon atom. First the supply was in the form of coal that has been mined as far back as by the Roman Empire and which formed the bedrock of the industrial revolution; and then it came in the form of hydrocarbons like crude oil and natural gas.

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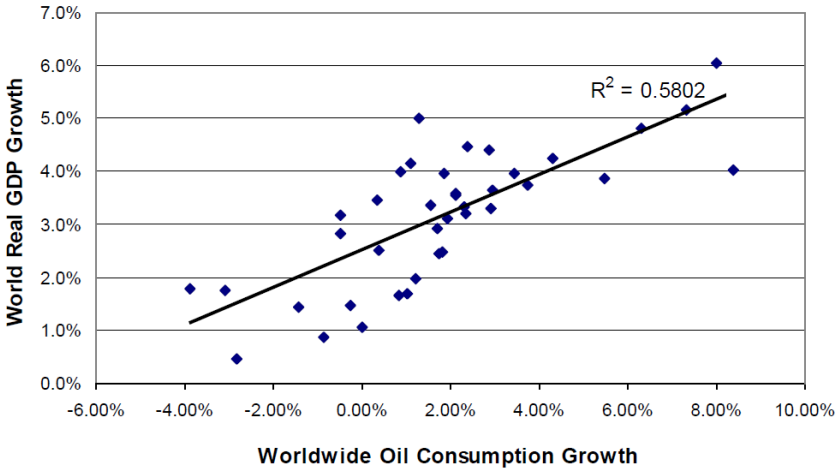
Picture 7.1. Correlation GDP Growth and Growth in Oil Consumption



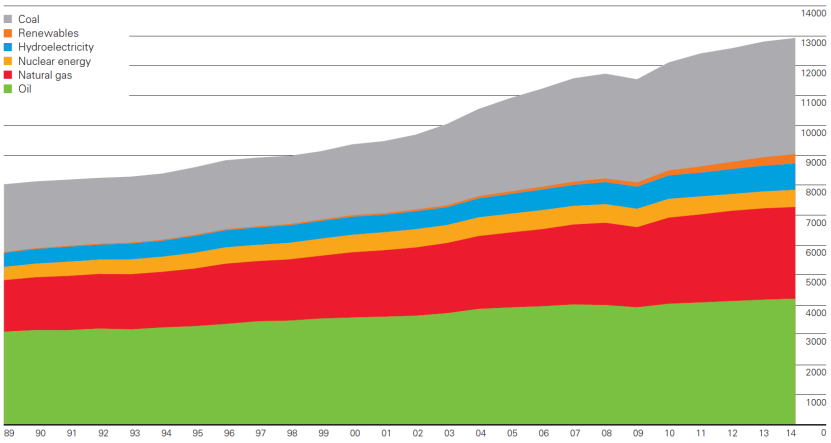
Source: IMF, 1969 - 2008

Oil, coal and gas = 87%

Mtoe – million tonnes of oil equivalents

The energy consumption of the world is divided into three large coal based fuel blocks where oil so far is still the largest with 33 percent of the usage in 2014. Perhaps surprising to some, coal is second with 30 percent and natural gas is third with 24 percent. The absolute majority of oil is used as fuel for transportation while the other two give us electricity and heat. Then there are three non-fossil fuel sources, of which hydropower is the largest with 6.8 percent, nuclear comes second with 4.4 percent and the fast growing renewables supply 2.5 percent of the energy used on Earth. The common yardstick for the sources of energy allowing us to compare them apples to apples is called mtoe, or million tonnes of oil equivalent.

Picture 7.2. World Energy Consumption, mtoe



Source: BP Statistical Review of World Energy 2015

The consumption varies between regions though. Renewables might be a very small part of the global energy supply but in Europe and the Americas the percentages are not negligible and as the share is growing renewables are effecting the energy supply systems. In fact renewables accounted for 1/3rd of the global growth in 2014. The other main difference between regions is the

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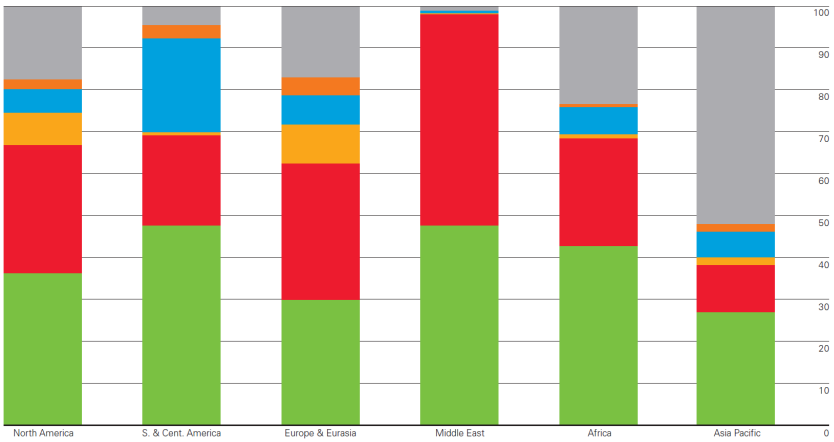
lack of coal usage in the Middle East while a full 52 percent of Asia Pacific's energy comes from this mineral of fossilized carbon.

US and China dominate

Looking deeper at the world's energy usage there is in effect just two countries that dominate and to no one's surprise it is the US and it is China. Those two countries account for 41 percent of global energy usage. As a comparison Sweden and Norway use 0.4 percent each.

Coal supplies 66 percent of China's energy and this country alone uses up 51 percent of the yearly coal consumption globally, Germany uses up 2.0 percent. In fact China's coal consumption alone if put in relation to the entire energy consumption of Sweden is over 38:1 (and it is 1/5 larger than the total energy consumption of the entire EU). Or to look at it another way, China's coal consumption put in relation to all renewables globally is a factor of 6:1.

Picture 7.3. Regional Energy Consumption, %



Source: BP Statistical Review of World Energy 2015 (same colors as in picture 7.2)

OECD – stagnant energy demand

Emerging Markets – growing energy demand

The regions also show different usage growth rates. The OECD-area have shown flat to stagnant energy use for a decade. In fact, 2014 energy consumption in the EU fell to its lowest level since 1985. It has for a long time been the Emerging Markets alone that drive the increase in energy consumption. Thus, the current economic deceleration for China impacts the global energy growth numbers. The combination of a slowing coal dependent Chinese growth and good momentum for renewables meant that the CO_2 emissions "only" grew by 0.5 percent in 2014, the lowest for many years.

GDP energy density in decline since the 1970s

Despite the strong correlation between energy usage and economic growth the relationship differs between regions as shown below in picture 7.4. Further, the energy intensity in the world's economic growth has been decreasing since the 1970's and is expected to continue to do this – especially as China seems to be steadfast in their switch towards a consumer led economy. A larger and larger part of the global economy consists of services, software, finance etc. that require relatively less energy to expand. Correlations only tell you that two factors move in tandem, it doesn't say that they move an equal amount.

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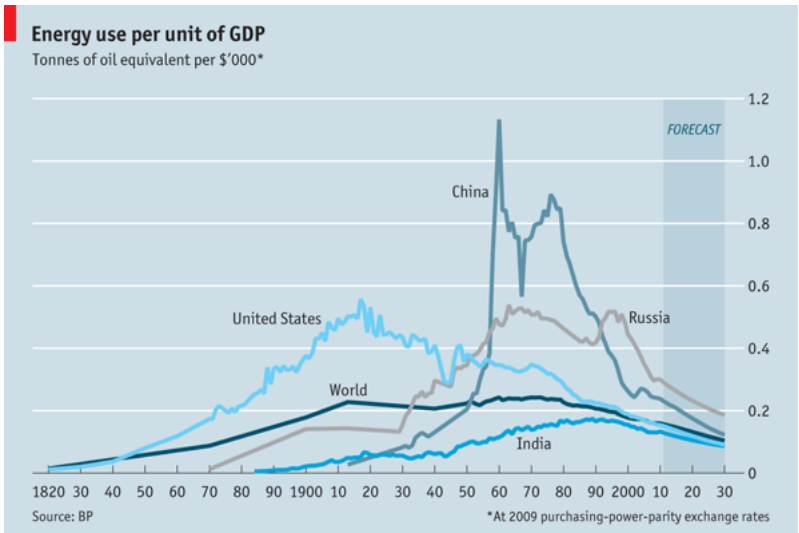
Picture 7.4. Energy Intensity of GDP Growth



Source: BP Statistical Review of World Energy 2009

Make no mistake though, save potential cyclical downturns, the total energy usage will increase in the immediate future. The world population is increasing and it is by the United Nations expected to reach about 11 bn by the year 2100. On top of this we are in the midst of the largest wealth increase in global history as Emerging Markets in rapid pace leave the worst poverty levels.

Proven reserves say relatively little

Longer-term is a different topic, but the production of oil and gas will increase in the foreseeable future. At the same time the proven reserves of oil and gas continue to increase (while those of coal are decreasing). At the current rate of production the global proven reserves of oil at the end of 2014 will last 53 years, natural gas 54 years and coal 110 years. The concept of proven reserves is however a treacherous one as we will see further on and the numbers say relatively little.

Reserves

1. Venezuela
2. Saudi Arabia

Obviously oil reserves are not evenly distributed across the world. The Middle East is the epicenter of oil reserves but the large recent offshore findings in South and Central America has improved the region's importance markedly. Venezuela officially held the largest part with 18 percent of global reserves in 2014 – albeit of lower quality heavy oil - followed by Saudi Arabia with 16 percent and the US 10 percent. OPEC in total held 71.6 percent of the proven reserves.

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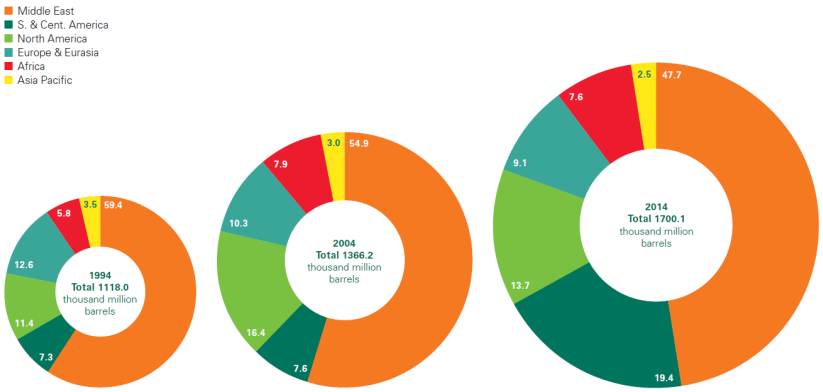
Picture 7.5. Distribution of Proven Oil Reserves in 1984, 2004 and 2014, %



Source: BP Statistical Review of World Energy 2015

US largest energy consumer but declining energy deficit.

In 2014 world production of oil was almost 90 million barrels per day. Some regions – typically non-OPEC countries - produce oil at a higher ratio of their reserves than others – typically OPEC countries. Hence, the largest producers differ from the holders of the largest reserves. Not as much as the producing regions differ from the consuming ones though. Asia Pacific is a relatively oil poor region but it is by far the largest oil consumer. A comparison between the US and China illustrates the point. The US was in 2014 the largest consumer of oil with a 19.9 percent of world consumption. However, the US also stood for 12.3 percent of world production and this number is increasing fast. The current price changes will stir things up but the prospect of North America becoming a net exporter of oil is a realistic one.

China second largest energy consumer with larger energy deficit

China is the second largest consumer with 12.4 percent of consumption but only accounts for 5.0 percent of production. The numbers for India are 4.3 percent and 1.0 percent; for Japan 4.7 percent and 0 percent. Looking at percentage share of oil production minus the share of oil consumption the outliers are Asia Pacific that have a 24.5 percentage point deficit while the Middle East have 22.4 percentage point surplus.

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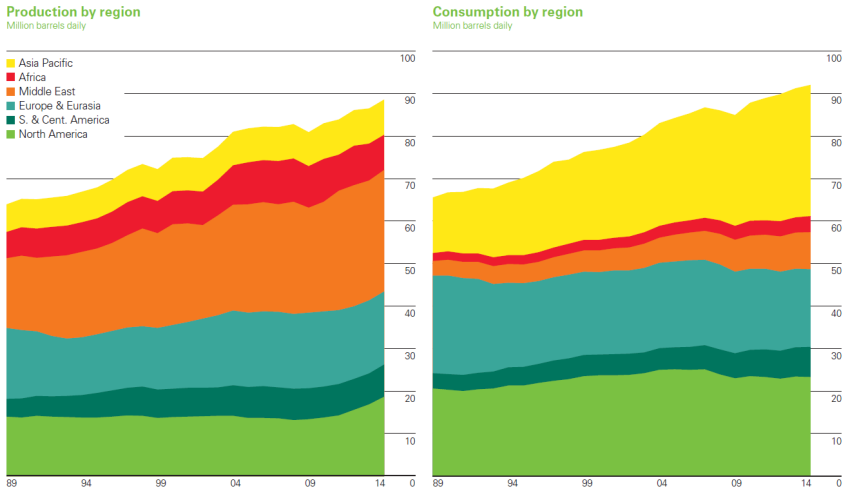
Picture 7.6. Production (left) and Consumption of Oil by Region (right)

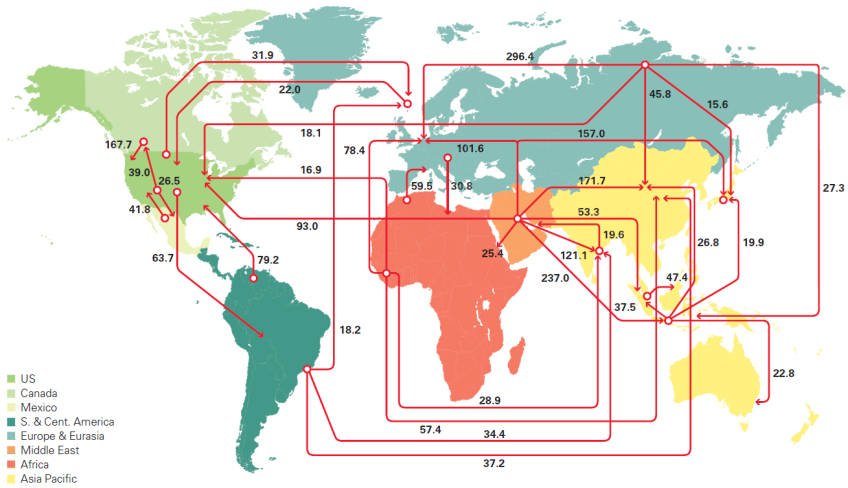


Source: BP Statistical Review of World Energy 2015

US lifted the 40 year export ban in October

The regional imbalances between supply and demand create a vibrant world trade in oil. The picture below might be a bit crowded but notice the large flows of oil in 2014 from Russia to Europe, from the Middle East to Europe, from the Middle East to Asia Pacific and from Canada to the US. The trade flow between the US and the Middle East is important but is not among the largest. The prospect of an energy independent North America has vast geopolitical consequences and potentially also removes a risk premium from the oil price as the consequences of oil embargos and the like suddenly carry less risk for the world's largest economy. It's symptomatic for the new energy situation that in October this year US voted to lift their 40 year ban on crude oil exports – it's no longer needed for national energy security reasons.

Picture 7.7. Oil Trade Movements 2014, million tones



Source: BP Statistical Review of World Energy 2015

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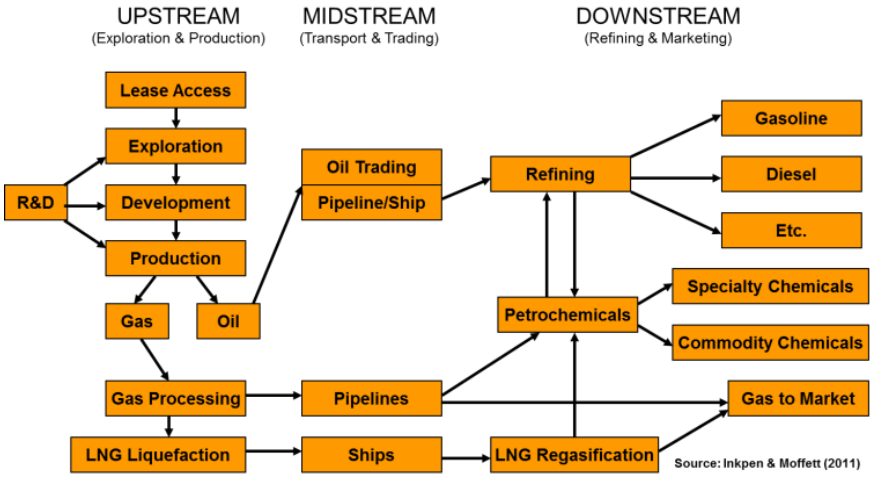
The oil industry can be divided into segments that correlate with the production chain. Most companies operate in just one of the segments but some of the big ones called integrated companies populate them all. The picture below gives an overview of the oil and gas value chain.

Picture 7.8. The Oil and Gas Value Chain



Upstream activities include exploration, development and production and are often performed in partnership structures involving several companies. The midstream comprises of storing, trading and transporting oil and gas. Liquids are easier to transport than gases making oil a global market and natural gas local markets. With liquefied natural gas, LNG, natural gas pricing will probably globalize over time. Downstream activities refer to refining plus the selling and marketing of end consumer products like gasoline. At times the midstream activities are included under the label of downstream. At times the then combined segments are called Gathering & Processing (G&P). Despite receiving its feedstock from hydrocarbons the petrochemical industry is not part of the oil and gas industry as defined by GICS and will be covered in a later industry primer.

Value Chain

- Upstream – exploration and production
- Midstream – transport and trading
- Downstream – refining and marketing

Hence, the companies in the industry search for oil and extract it. Alternatively they distil the oil and gas into end consumer products or they do both. Some of the companies are private and some are government owned. Then there are a number of adjacent service companies that serve a niche and live of the opex or capex of the larger companies.

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7.2 History And Geopolitics

1846: The world's first drilled oil well in Baku

Our history of oil begins a short distance outside Baku which today is the capital of the Azerbaijan Republic when the world's first drilled oil well was completed in 1846. Before this the paraffin factory in Baku, that at the time was a town in the Russian empire, was supplied from hand-dug oil wells. The natural resources around Baku soon caught the eye of international finance and within short the Nobel family and the Rothschild family were in competition with the domestic producers giving rise to an oil boom where Baku's population exploded and the futuristic luxury of automobiles were seen rolling on the streets as early as in 1907. Oil reservoirs are seldom placed at the same place as the consumers so transportation is a constant issue. For the purpose of ferrying the Caspian Sea Ludwig Nobel, the "Russian Rockefeller", had the world's first oil tanker called Zoroaster built at Motala works' shipyards in Norrköping in 1877. Soon thereafter the former British shell merchant Marcus Samuel and his brother Samuel Samuel founded Shell Oil in Baku.

Picture 7.9. Zoroaster, the first oil tanker

Source: vesslfinder.com

1859: Edwin Drake strikes oil in Pennsylvania

On the other side of the Atlantic Colonel Edwin Drake was hired a few years later by the Pennsylvania Rock Oil Company to drill for oil to replace the use of expensive whale oil in lamps. In 1859 Drake's driller Billy Smith hit oil in his first attempt with a 21 meter deep well that took 5 months to drill and produced about 15 barrels a day. The picture below shows Drake and Smith in front of the original equipment and engine house that was destroyed in a fire two months after the discovery. Drake's discovery and the high prices for oil as a substitute for the scarce whale oil started a rush for the black gold. When pictures of the "Lucas gusher" at the Spindletop field in Texas which in 1901 blew out oil for nine days was cabled out by newspapers the rush turned into frenzy. Very quickly the US became the world's leading oil producer. Suddenly there was enough oil to venture outside the use for lighting.

Spindletop

As the industry grew a number of new technical designs emerged including the well site, bottom-hole, submersible pumps made practical by the advent of electricity. The mechanism allowed the shaft to rotate in opposite directions during the up- and downstrokes improving the efficiency. At the Spindletop

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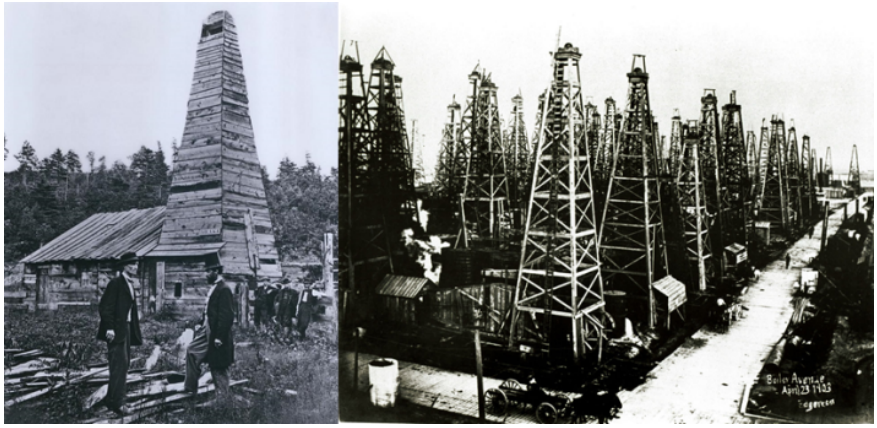
field a practice of circulating drilling mud in the drill hole was commenced. The mud helped remove cuttings from the hole, cooled the drill and prevented the hydrocarbons from rising to the top in an uncontrolled way. At about the same time the introduction of cement casing around walls of the drill hole solved some of the problems with water intrusion.

Picture 7.10. First American oil well in Oil Creek (left), Pennsylvania & Spindeltop oil field, Texas (right)



Sources: aoghs.org (left), bloomberg.com (right)

Standard Oil Company

The new booming industry was soon aggressively consolidated by a man who previously had purchased a refinery in Cleveland and in 1870 started his Standard Oil Company. The consolidator was John D. Rockefeller. Colonel Drake stored the first of his newly found oil in a bathtub before switching to a wooden fish oil container. Others just pumped the oil into a sump and then shipped the oil off in wooden barrels. Much of the transportation of US oil was dependent on horse carriages carrying oil in old whiskey and whine barrels of various sizes. Standard Oil standardized the volume of a barrel to be their Standard Oil painted blue barrel (or bbl) which was 42 gallons and that is still used today as the standard measure - despite very little oil being transported in barrels (1 gallon = 3.78541 liters, 1 barrel = 42 gallons = 158.98722 liters). Given today's large traded volumes of oil the standard measure is thousand barrels per day, or tb/d.

Bbl – (blue) barrel

1 bbl = 42 gallons = 159 liters

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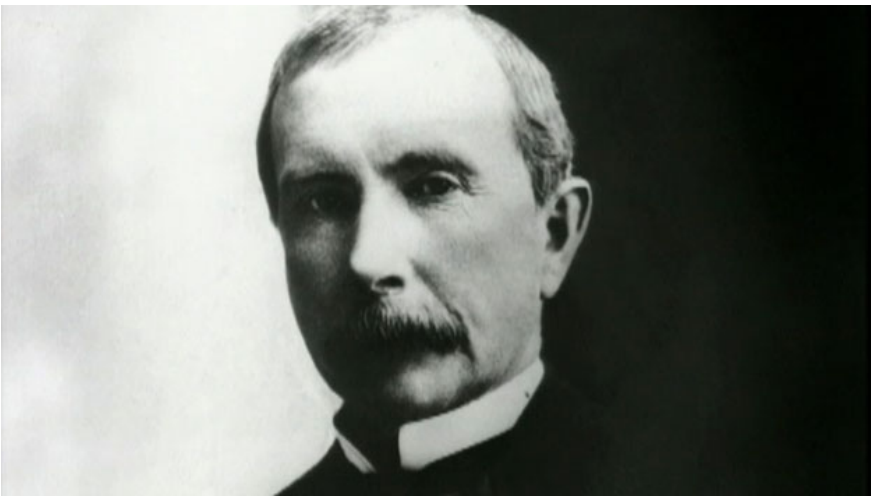
Picture 7.11. John D. Rockefeller



Source: empireonline.com

Already by 1890 Rockefeller controlled 90 percent of the US oil market in what effectively was a monopoly. The situation caused much public debate on anti-competitive practices, Rockefeller became the popular embodiment of the Robber Barron and in 1911 the Standard Oil Company was mandated to split up into 34 companies. Ironically, the split companies became far more valuable than the original Standard Oil so in effect the break-up further added to Rockefeller's enormous wealth.

The rise of the Middle East

Oil findings all around the world were now being made. In 1890 Royal Dutch discovered oil in the Indonesian island of Sumatra and in 1908 the Anglo-Persian Oil Company (nowadays called BP) struck oil in Persia, today's Iran, paving the way for the subsequent rise of the Middle East as a powerhouse of oil and gas. Saudi Arabia came relatively late to the party as today's Chevron and Texaco found oil only in 1938. Even today Saudi Arabia produces from relatively few but large oil fields including the largest field known to man, the Ghawar. Oil fields are often classified by the size of their so called probable reserves where they in descending size order are called super giants, giants, large and other. The first two types are sometimes called elephant fields and Ghawar is a true elephant that's been in production for 65 years.

The Seven Sisters

IOC – integrated oil companies

Over time several of the previous parts of Standard Oil merged again and with the addition of a pair of international competitors a group of companies sometimes called the Seven Sisters gradually came to dominate the global oil production. The Seven Sisters were the Standard Oil Company of New Jersey, the Standard Oil Company of New York, Standard Oil of California, Texas Company, Royal Dutch Shell, the Anglo-Persian Oil Company and Gulf Oil. These companies are the origins of today's oil majors, or so called integrated oil companies (IOCs).

Technology of course continued to develop. In the 1930s it was discovered that if acid was pumped into old wells that were turning dry the oil production increased, thus establishing the principle of well stimulation. Halliburton Oil

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Offshore drilling

Wildcat drilling - drilling in previously unproven areas and those who drill wildcat holes are called wildcatters

Well Cementing Company begun to offer hydraulic fracturing services in the 1940s. The technique of horizontal drilling using a downhole motor was developed by Elf Aquitaine in Europe during the 1980s. Offshore drilling had started with drilling from piers in shallow waters where oil and gas seeps could be observed. In 1947 the first wildcat drilling was performed from a location out of sight from land 40 miles off the Louisiana coast. When Shell in 1989 installed the 55,000 ton Bullwinkle platform expanding offshore production to deep-water areas the number of exploitable reservoirs took a significant leap.

Picture 7.12. The first off-shore drilling at Summerland, Santa Barbara, California

Source: kcet.org

Qaddafi ruins the party

The oil weapon

For long the standard set up between the Seven Sisters and the governments in the oil producing countries was a concession that in effect meant a 50/50 profit sharing. The oil company handled the exploration and production and got half of the proceeds and the government gave the concession to the land and also got half. There was no doubt a fair amount of collusion among the major oil companies as all the players were in all the assets. This set-up and the power of the Seven Sisters started to crack in the 1970's. By threatening to nationalize their assets Muammar al-Qaddafi of Libya got Occidental Petroleum to diverge from the 50/50 split and soon a race was on where the governments received much larger cuts. Further OPEC for the first time in 1973 used the "oil weapon" when 6 of the members stopped supplying Europe and the US with oil in support of Egypt and Syria in their surprise attack on Israel. In parallel with OPEC's growing importance nationalization of oil producing facilities picked up momentum.

NOC – National Oil Compay

Nationalization, whereby the IOC's concession rights and production facilities are either bought at varying prices or seized without compensation by a so called national oil company (NOC), had begun in an anti-colonialist campaign in Mexico 1938, followed by Iran and Egypt in the 1950's and then swept over

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Nationalization and the rise of the NOC

the world in the 1970's including the Saudi overtake of what was to become Saudi Aramco. Today NOCs control 85 percent of the world's hydrocarbons and IOCs and other independent E&P companies split the rest. The first oil shock of 1973/74 was followed by a second politically induced oil shock 1978 to 1981 and Saudi Arabia - despite being the low cost producer took on a role as the swing producer trying to control oil prices.

Government take 70%

The so called government take is today generally between 50 and 90 percent but there are instances of both higher and lower takes than this. Often OECD and South American government takes are on the lower end. Frequently when the oil price drops governments are under more pressure offering more attractive terms for the producing companies – and vice versa. On average the government take is around 70 percent. Ironically, irrespectively of if one is of the opinion that the war in Iraq was fought over oil or not; the Iraqi post-war contracts had much higher government takes than the global average, effectively leaving little profits for "big oil".

IEA – International Energy Agency

LNG – Liquid Natural Gas

The oil shocks had as much a political impact as economic, since energy security, i.e. the availability of sufficient energy supplies at affordable prices, rose to the top of countries agendas. The International Energy Agency (IEA) was formed to counterbalance the power of OPEC. The members of IEA take on a responsibility to store strategic petroleum reserves to be called upon when the organization so demands. In many countries oil was replaced by coal and gas for industrial use and in power generation. Japan and Korea decided to diversify their energy usage and started to import liquid natural gas (LNG). France and a few other countries embarked on a massive build out of nuclear energy for the same reason. Further, the oil shocks kick-started a global drive to promote energy efficiency. Changes in prices drive changes in behavior.

The rise of non-OPEC…

…and a price collapse

In reality the second oil shock marked the peak of OPEC's power as the production of non-OPEC hydrocarbons increased massively in volume at this time. The Soviet Union had risen to the second largest energy producer behind Saudi Arabia and despite the socialist rhetoric picturing USSR as an industrial nation the country was in effect a petro-state. Further, in 1969 after drilling 32 dry holes in the North Sea Philips Petroleum decided to drill one last hole and if this turned out dry, a duster, they would abandon the sea between Great Britain and Norway. In their last attempt they found the giant Ekofisk field and North Sea oil gradually began to flow. During the 1980's and 90's the oil prices collapsed from the increased supply and from Saudi Arabia's and other OPEC member states' decision to compensate for the lower prices with higher volumes to be able to support their nations' growing welfare programs. The price collapse also meant the end of the Soviet Union which could no longer finance its state budget.

NYMEX – New York Mercantile Exchange

IPE – International Petroleum Exchange

Another development contributed to the declining power of OPEC. Up until the 1980s oil prices had been negotiated between industrial buyers and sellers behind closed doors. In 1983 the New York Mercantile Exchange (NYMEX) opened up trading in crude oil futures. In 1988 trading commenced at the International Petroleum Exchange (IPE) in London. The pricing of crude oil quickly became more transparent and handled by screaming men in ugly

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WTI – Western Texas Intermediate

colorful jackets. A trade in "paper barrels" established itself in parallel with the trade of the physical product. Western Texas Intermediate (WTI) and Brent crude established themselves as the main global exchange traded oil price benchmarks. NYMEX alone has a daily turnover of oil futures and options that is 10 times the daily volume of physical oil demand globally.

Picture 7.13. NYMEX

Source: reuters.com

Merger mania

Pressured by the low energy prices plus the rise of the NOCs and faced with an ever increasing scope of development projects the Seven Sisters got caught up in a wave of mergers starting with the BP-Amoco deal in 1999. When the dust settled we had today's setup of IOCs with ExxonMobile, Chevron, BP, RoyalDutch Shell, ConocoPhilips and Total. They came out more globalized, more efficient and with better capacity to take on large-scale projects.

Chinese demand shock

It took until 2004/05 before demand caught up with the ample supply and after decades of oil prices which had hovered around USD 20 to 25, finally the price started to rise. During the prior decades violent short-term price spikes had been the effects of supply shocks, i.e. disruption in the supply for any more or less politically induced reason. What caught the oil industry off guard was that the demand/supply balance in 2004/05 was changed by a structural (as opposed to cyclical) demand shock caused by the meteoric economic growth of Emerging Markets and China in particular. The Chinese growth to become the largest user of energy on the planet effectively melted away the oil producers' spare production capacity. Low prices had meant stagnant oil and gas investments for a very long time. Refining capacity basically had been static since the 1970s. Now things changed.

As for other importers of energy, energy security has now become a critical point for China. About two thirds of the world's traded LNG, half of the world trade, 80 percent of Japan's and Korea's oil imports and 40 percent of China's

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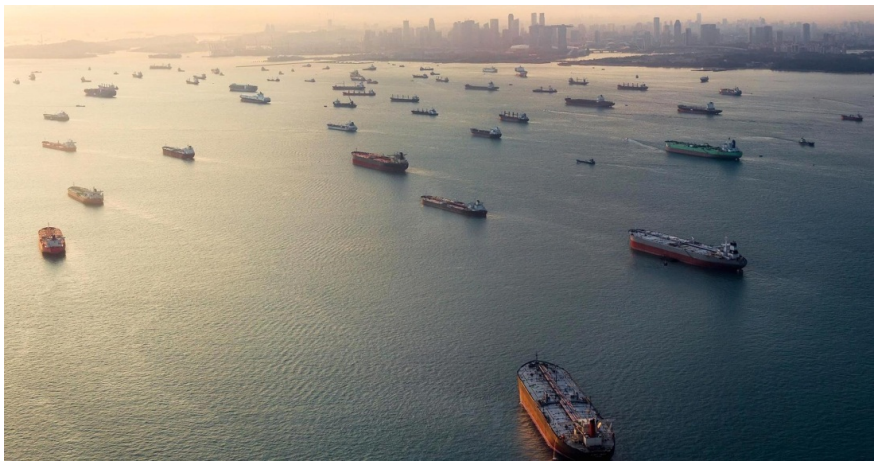
pass through the 805 km long and at its most narrow only 64 km wide Strait of Malacca. The emergence of a more active and aggressive Chinese marine fleet in the South China Sea should surprise no one.

Picture 7.14. Ships outside Singapore in the Strait of Malacca



Source: cnbc.com

Putin's petro-state…

With the higher prices many of the authoritarian petro-states like Nigeria or Hugo Chávez's Venezuela saw a revival. None more so than Vladimir Putin's Russia. In line with the map to restore Russia as a "great economic power" that Putin sketched in 1999 in an article in the St. Petersburg Mining Institute's journal, he had by various means consolidated the oil and gas resources direct under the control of the state, i.e. himself. Despite the collapse of the Soviet state and the chaos that followed, Russia was once again the second largest producer of oil and gas in the world. The only sour grape was that Putin had lost his grip of oil rich regions like Kazakhstan and Azerbaijan with its capital Baku. They now built their own pipelines to the Mediterranean Sea staying well clear of Russian soil.

The geopolitical aspects of energy became evident when Russia shut down the gas pipelines to a not sufficiently subdued Ukraine in 2006, thereby causing a shortage of gas in Europe that at the time imported more than a quarter of its gas from Russia. The event caused Russia to build additional differently routed pipelines to Europe and at the same time it caused Europe to try to diversify away from Russian gas.

…challenged by the son of a goat herder

However, the resurrection of the Russian empire was to be severely challenged by the son of a Greek goat herder called George P. Mitchel. It has long been known that large quantities of gas are contained in shale rock. The problem was that it was hard and expensive to extract the gas making the economics a non-starter. Mitchel's relentless work over several decades experimenting with different technologies in 1998 lead to a break-through using hydraulic fracturing to extract the trapped gas. When teaming up with Larry Nichols of Devon energy with expertise in horizontal drilling the code for extracting shale gas and shale oil was cracked and the US shale revolution was in motion. The non-OPEC supply of oil rose spectacularly between 2009 and

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2014 thanks to the increased US output. A whole new boom industry of small-scale developers emerged additionally fueled by the cheap money of FEDs QE policies. Instead of becoming the main purchaser the US became a LNG exporter. Just as in the 1980s the oil price collapsed from the increased supply in 2014/15. The last time this happened the rulers of the Kremlin had to surrender power.

7.3 What Is Oil?

Pounds per square inch (psi) - underground pressure

Some hundreds of million years ago the organic matter of dead plants and micro-organisms ended up in anoxic places like on the bottom of the sea. As they weren't broken down they were subsequently covered by sediment and buried underground. Under the earth's surface two factors went to work. The weight increased and the temperature went up. The load on an object underground is measured in pounds per square inch (psi). The psi increases roughly with one pound per foot. 5,000 feet underground the pressure is about 5,000 psi, that is 1.5 km underground the pressure is about 2,3 tones per square inch. Add the high temperature at that depth due to the proximity to the inner parts of our planet plus millions of years and you've got the making of the chemical reaction that creates hydrocarbons.

Kerogen

In a first step the solid matter kerogen is created. As the molecules of kerogen are broken down further, lighter hydrocarbons like oil and gas are created. The further underground the higher the psi and the heat. This means that kerogen at a depth of 2.3 km to 4.6 km is broken down to oil while kerogen below this "oil window" is broken down to gas in what's called the "gas window". Above the oil window, in the "kerogen window", the kerogen doesn't transform to a lighter molecule.

Organic Chemistry

Valence – propensity to connect to a specific # of atoms

Bond – the connection between atoms

Hydrocarbons are combinations of carbon atoms and hydrogen atoms connected in countless variations. In chemistry hydrocarbons are studied in the area of organic chemistry - the chemistry of carbon. An atom has the propensity to connect to a specific number of other atoms. This propensity is called valence and the connections between two atoms are called bonds. Carbon has a valence of 4 while hydrogen has a valence of 1. Thus the simplest hydrocarbon contains of one carbon atom and four hydrogen atoms. Together they form methane, the bedrock of natural gas.

Now, through the four bonds of the carbon atom and the one bond of the hydrogen atom it is possible to build an endless amount of molecules structured in the most complex ways. If arranged in a row they are called paraffin. Naphtenes have cyclic shapes. Aromatics lack one hydrogen atom forcing the carbon atom to form double bonds with another atom. Asphaltenes look like broken up chicken wire. The more atoms in the molecule the heavier it is. Methane is the lightest and asphaltenes are among the heavier. Paraffins have a waxy character.

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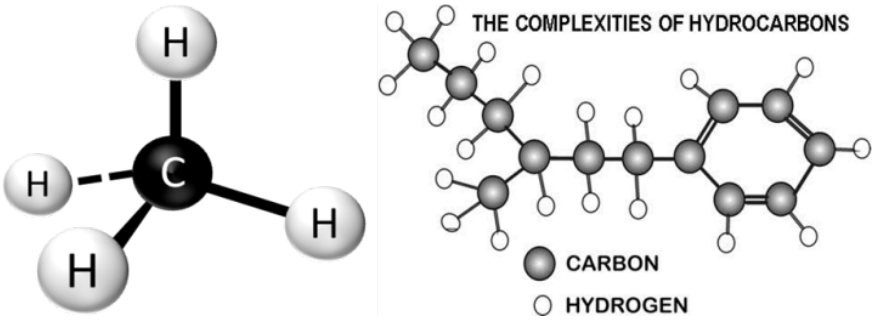
Picture 7.15. Methane (CH4) and hydrocarbons



Source: sciencegeist.net (left) and bofep.org (right)

Crude oil – a mixed slush

Crude oil is as such an anarchistic mix of millions of different types of hydrocarbons. Some oil may be classified as paraffinic crude but this only means that it contains a relatively larger number of paraffin molecules than naphthenic crude or aromatic crude. In reality they are all a mix of all sorts of hydrocarbon molecules. Typically crude oil contains 84 to 87 percent carbon atoms, 11 to 14 percent hydrogen atoms and 1 to 5 percent other atoms like sulfur, nitrogen, oxygen, metals and salts.

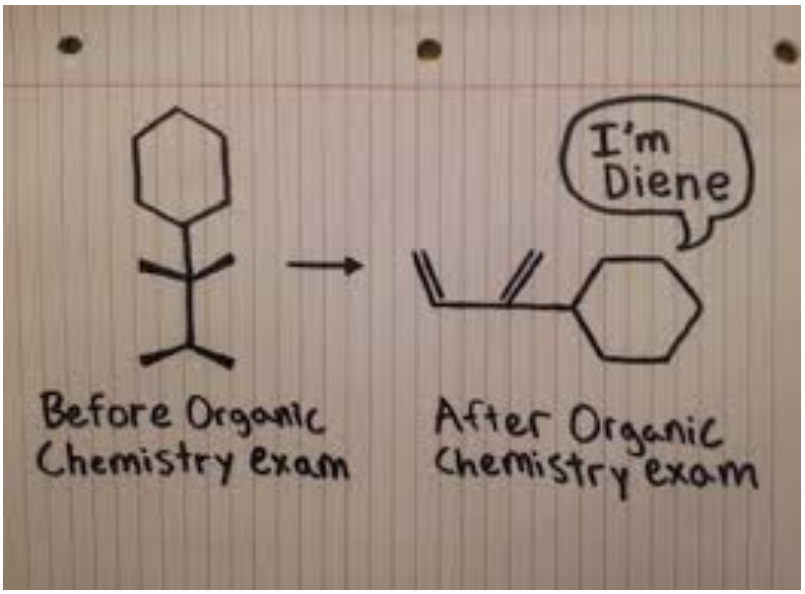
The primary attraction of hydrocarbons is that hydrogen atoms release heat when combined with oxygen in a process we mortals call burning but the chemists call oxidization. For example:

Heat is kind of important

$CH_4 + 2O_2 = CO_2 + 2H_2O + heat$ or *methane + oxygen = carbon dioxide + water + heat*

This byproduct heat is what drives our cars, powers the steel mill and lights our bedside lamp.

Picture 7.16. I'm Diene ☺ - Chemistry humor, sorry…



Source: thematapicture.com. A diene is a hydrocarbon that contains two carbon double bonds. It's often used to bind two molecules together in the polymer industry.

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Petroleum engineers use the hydrocarbon mix to categorize different kinds of oil and gas:

Hydrocarbon mix
- Dry gas
- Wet gas
- Natural gas liquids (NGL)
- Condensate
- Light crude oil
- Heavy crude oil
- Bitumen

- Dry gas is natural gas that almost entirely consists of methane which is the most commercially marketable part of the gases.
- Wet gas is natural gas that contains a high percentage of methane but also natural gas liquids and ethane, propane, butane etc.
- Natural gas liquids (NGL) are very light hydrocarbons that are gaseous at standard atmospheric pressure but can easily be compressed or cooled to liquid form. NGL generally don't contain methane.
- Condensate is also a very light crude oil that contains amounts of gas and that comes from a well that predominantly produces gas. Condensates that are gaseous in the well with its high pressure but condensates to a liquid at the surface are sometimes called the Champagne of Crude because they are so easily refined into high value products like gasoline.
- Light crude oil contains a few percent natural gas liquids and has low wax content.
- Heavy crude oil contains no natural gas liquids but instead many heavier hydrocarbons.
- Bitumen is a mix of heavy hydrocarbons.

°API – specific gravity measuring (relative) density or weight

The weight or density of the hydrocarbon mix is measured in °API ranging from 0 to 100. This is a measure of so called specific gravity that measures the weight of a given material compared to the weight of an equal volume of water. The tricky thing to remember is that a higher °API number means a lower weight. That is, a heavy crude oil like Venezuela's Bachaquero has got an °API of about 17 while a light crude oil as West Texas Intermediate has got an °API of 40 (similar to Brent's 38.5). Very light crudes are often green in color. Heavier hydrocarbons are instead black.

Centipoises (cp) – measuring viscosity, a fluids resistance to flow

Weight is not the only characteristic of the oil. Viscosity measures a fluids resistance to flow, its thickness. Viscosity is measured in centipoises (cp). Viscosity changes with temperature since long entangled hydrocarbon molecules stretch out and lose their grip of each other when heated. The pour point measures the lowest temperature at which a crude oil will flow. Low pour points are preferred since the fluid will flow also in chilly weathers. The higher the paraffin content of the crude the lower the pour point.

Unfortunately, as noted above, oil and gas reservoirs don't just contain hydrocarbons. A number of other contaminating molecules are present in the gases. Examples in natural gas are carbon dioxide, oxygen, nitrogen and the deadly toxic pollutant hydrogen sulfide. These molecules must be removed before the producer has a commercial end consumer product to sell. Apart from large measures of water, crude oil suffers from the presence of amongst other sulfur and metals.

Sour crude – over 0.5% sulfur

Sweet crude – under 0.5% sulfur

Crude oil that contains more than 0.5 percent sulfur is called sour crudes and the sulfur comes with a stink of rotten-eggs. The oil with a lower sulfur content than this limit is called sweet crudes. Most of the sulfur has to be removed before the oil is allowed to be used. This could be a cumbersome

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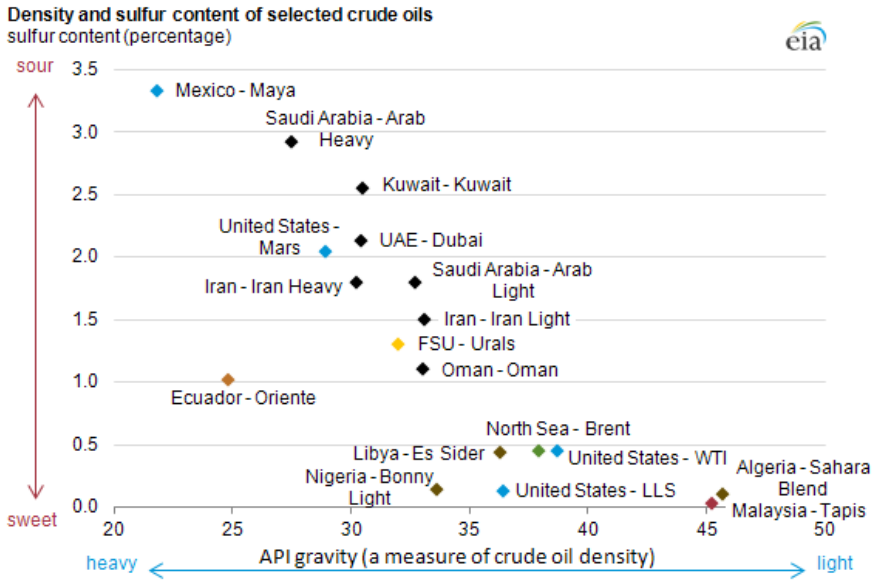
process since much of the sulfur is not only dissolved in the oil but has also reacted with the hydrocarbon molecules and are attached to them.

Light and sweet > heavy and sour

As is evident, not all crude oil reserves are made equal. The combination of light vs heavy oil and sweet vs sour oil is a usual way to categorize crude oil. You obviously prefer to be in the lower right light-sweet corner as it will yield a higher proportion of high value lighter products such as gasoline and will be cheaper to process. As the good stuff has been explored and depleted first, the mix of sour oil has increased in the crude production over time.

Picture 7.17. Classification of crude oil



Source: EIA

Petroleum – "rock-oil"

As a side note, the word petroleum is derived from the Latin petra which means rock and oleum which means oil.

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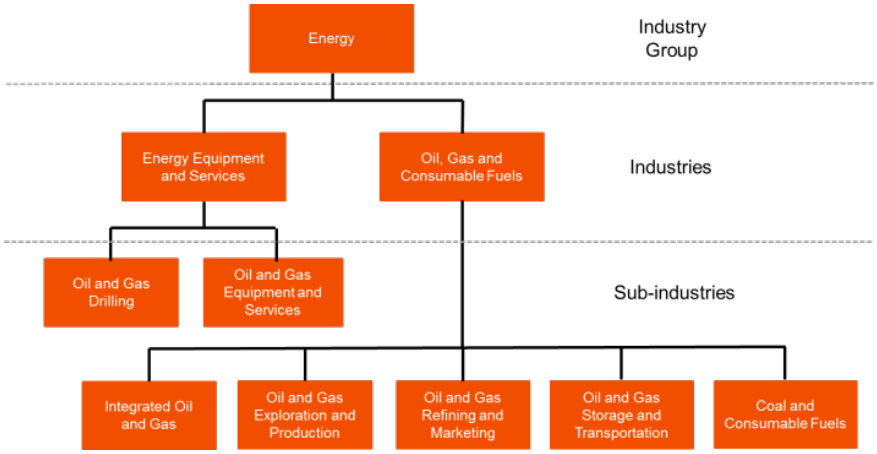
7.4 The Players

GICS – Global Industry Classification Standard

GICS has divided the Energy industry group into two industries where the industry called Oil, Gas and Consumable Fuels follows the production chain and Energy Equipment and Services support those in the production chain with supplies and services.

Picture 7.18. GICS Classification of Energy Companies



Source: Global Industry Classification Standard

GICS definitions are relevant to understand the universe of listed oil and gas companies where the sub-industry in the bottom left corner called Integrated Oil and Gas is the largest one in market capitalization. However, it misses who the real dominant players are in the industry.

National Oil Companies (NOCs) and the Petro-state

The by far most dominant players on the global oil and gas market today is the national oil companies of countries that at times can be described as petro-states where 50, 70 or even 90 percent of the economy is dependent on the sale of hydrocarbons and that because of this often are highly distorted as economies and societies.

NOC – government owned and often controlling a country's oil reserves

NOCs can be found both among the OPEC countries and among non-OPEC countries. Among the former are Saudi Aramco of Saudi Arabia which is the largest oil company in the world, NIOC of Iran and PDVSA of Venezuela. Among the latter are PEMEX of Mexico, Petrobras of Brazil, Rosneft of Russia and many others. Not all NOCs are resource rich. In India and China they are rather vehicles for ensuring energy security by gaining access to international energy resources making them act like IOCs. China has three large NOCs called China Petrolium & Chemical Corporation (Sinopec), China National Petroleum Corporation (PetroChina) and Chinese National Offshore Oil Corporation (CNOOC).

A NOC is a company controlled by a government, often formed to manage the country's hydrocarbon recourses and as such an arm of a government ministry. Some are partially private owned. The most important trend in the

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oil industry the last 50 years has been the growing importance of NOCs and today they control over 85 percent of the world's oil. Saudi Aramco alone has more oil reserves than all the traditional oil majors combined. If privatized and listed it would no doubt dethrone Apple as the world's most valuable company. PDVSA has even larger reserves than Saudi Aramco but the crude is heavier, the extraction cost is higher and the state of the company leaves much to wish for. As NOCs become more global and some even list some of their shares the boundaries between NOCs and the traditional integrated oil companies blur and mostly relate to the preferential access to a country's oil and gas.

The shining star Norway

NOCs have a very mixed business track-record and overall it is safe to say that the nationalizations almost universally have failed to live up to initial expectations. Underinvestment in equipment, technology development and knowledge has been a chronic problem as politicians have preferred to pool resources to popular social reforms – or to their own pockets. Of course there are exceptions and one is Statoil of Norway and perhaps PETRONAS in Malaysia is another. Further, in several countries in the Middle East oil has driven positive economic development. Increasingly NOCs also leverage the knowledge of oil service firms. Because the oil service firms don't seek ownership rights to oil reserves their role as partners to NOC's has become very important. Through the oil service firms the NOCs can circumvent the need to involve the IOCs in the E&P-process.

The dominating economic activity in a petro-state is not to create value through innovation and productivity but to capture value out of the existing resources. Hard work, entrepreneurship and diversification of economic activity give way to clientelism, corruption and increasingly rigid bureaucratic controls. An extreme example of people trying to capture value out of existing resources is the practice of so-called bunkering in for example Nigeria. Bunkering is when bands of armed young men crack open and steal oil from the country's maze of pipelines without any regard for the environmental consequences that follow.

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Picture 7.19. Effects of Bunkering in Nigeria

Source: rockesci.co.ke

Dutch disease

The crowding out of other sectors made uncompetitive by the resource-based windfalls is often called the Dutch disease and leaves countries dangerously lacking future safety nets. Further, the energy sector is capital intensive but doesn't employ much staff leaving it outside of most people's day-to-day experience. When energy prices are high there are rapidly increasing expectations on social welfare programs diverting resources from necessary investments in the generally nationalized energy industry. When energy prices are low and the nation's revenues fall, few governments dare cut back on spending and risk a revolt. Perversely, low prices at times leads to increased production volumes to generate the same absolute amount of revenues. This of course just exacerbates the price fall. One of the shining examples of how to avoid most of these issues is Norway that simply sets aside almost all of the governmental proceeds from the oil and gas production and invests them in equities and bonds for a later rainy day.

INOC – International National Oil Company (contradiction in terms?)

That said the NOCs of this world are not one and the same. Their level of professionalism varies hugely. Some have since long moved outside their domestic borders to compete on the global arena giving rise to the hybrid sometimes called international national oil companies INOCs.

Since the foundations of most NOCs are expropriated assets from IOCs it could in some way be argued that John D. Rockefeller in part seeded these companies as well. Despite the lower than average efficiency it's safe to say that thanks to their access to the hydrocarbon reserves NOCs will play the lead violin for as long as the oil age continues.

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Integrated Oil Companies (IOC)

IOC – Integrated Oil Company
IOC – International Oil Company

An IOC (an Integrated Oil Company or an International Oil Company) is a company that operates in both upstream, midstream and downstream, that competes internationally across borders and that is in the hands of private owners. Generally this describes the big well known traditional oil companies ("Oil Major", "Supermajor" and "Big Oil" are labels often used) like BP, Shell etc. Despite being present in most parts of the industry, IOCs outsource a large part of their actual operations.

Lost out to NOCs

The future of any upstream oil company is its reserves in the ground. The strategy of an IOC is to gain access to upstream opportunities, take project risk and participate in the upside potential by gaining ownership of the developed oil reserves. They aim to build up a diversified portfolio of projects that balance reservoir prospects, flexibility of rights and commerciality of lease conditions. The IOCs strategy builds on that there is potential to acquire what they call equity oil - oil that they can book as their reserves. The tighter control of the reserves by the various states and their NOCs has enormous implications for the goals and strategies of IOCs. As late as 1970 it was the IOCs that controlled 85 percent of global oil reserves. Now it's the reverse. This means that IOCs have to develop skills and expertise that makes them hard to bypass when oil and gas exploration continues in ever more challenging environments.

Given that the governments that own the NOCs also own the oil exploration rights IOCs need to acquire a lease to get access to the oil. Many governments structure the leases as a profit sharing agreement that, to incentivize investments, allows the exploration company to deduct some of the investments and costs before splitting profits with the government. Other governments require a certain portion of the contract to be owned by their NOC and the profits to be allocated proportionally. At times a government wants a fixed monetary amount for each produced barrel of oil to transfer the price risk to the exploration company.

Irrespective of which system that is used and if the payments are in forms of royalties, taxes or fees etc. it's important to realize that the government take is the main "cost" for IOCs and other companies in E&P.

Independent Companies

A non-integrated private company generating its revenue from either E&P or from downstream operations like distilling is called an independent oil company. Most of the independent companies are active in E&P where they often take on riskier projects than the IOCs resulting in higher risk/reward for the owners. In the US the oil and gas industry has been fertile ground for private equity which has financed a significant part of the upstream businesses. E&P in itself is one of the segments with the highest risk/reward in the industry. Independent E&P companies commission for about 80 percent of the wildcat drilling. Large independent E&P companies are Apache and Anadarko.

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Oil Equipment and Service Companies

A race to be relevant

The entire production chain in oil and gas is dependent on oil service companies. No firm can or wishes to do all the tasks required in the oil and gas value chain. In the exploration and production of an oil reservoir there are dozens of companies involved. As the NOCs have increased their aspirations the oil field service companies have seen a chance to expand their business. They have to strike a balance however, as much of their business is drilling for the IOCs as well. When offshore drilling takes place in ever more deep and distant seas cutting edge technology has to be used. The IOCs and the oil field service companies are in an arms race to be the technology leaders. An IOC that want to contract an oil field service company must consider the risks of the service company learning valuable intellectual property that might be transferred to projects run by competitors.

OGD – oil and gas drilling

Drilling rig contractors (or OGD, oil and gas drilling) like Transocean have a business as most E&P companies don't own drilling rigs, instead they lease them. The rig contractors usually can supply the crew to operate the rigs but the customer can also choose to supply the crew by other means. The business is capital intensive and hugely cyclical with long periods of very low utilization and low prices, called dayrates, layered with periods of full utilization and exuberant prices. In good times there is a constant risk that too many rigs get built only to exacerbate the problems when the tide turns. This is a high beta play.

Oil service providers

Oil service providers are contracted by IOCs and NOCs to find and develop oil and gas reservoirs. They help out in almost every possible area. It could be seismic analysis, oil drilling, oil production, support services for staff. Companies can be small like most of the independent seismic service providers or they can be large offering a whole range of services. Two of the larger ones are Schlumberger and Halliburton. These companies don't own any oil but are contracted to perform a certain service. In addition to dayrates, drilling contractors can also enter into footage contracts, payment per foot drilled. This means that the risk that the drilling goes on longer than expected burdens the oil service company.

Roughnecks
Roustabouts

Thus, the people who provide drilling mostly work for drilling rig contractors or oil service providers and not for NOCs, IOCs or independent E&P companies. Some 90 percent of E&P spending of these is outsourced. The drilling crews contain several roles including the colorfully named 'roughnecks', i.e. the members working the rig flor, and their helpers the 'roustabouts'.

Oil equipment providers

Oil equipment providers (or E&S, equipment and service) rent and sell equipment like drill bits, piping, pumps and whatever product and service that is needed to explore and produce oil and gas – apart from rigs. This is a less capital intensive and more stable business than rig contractors.

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Refineries

Making crude into gasoline

A refiner produces end customer products like gasoline and diesel using crude oil as feedstock. The refiner is caught between two markets, the raw material he needs to purchase and the finished products he wants to sell. Because refiners are on both sides of the market their market risk exceeds those who simply sell crude oil at the wellhead.

Close to customers

There are several hundred refineries around the world including 4 in Sweden and 2 in Norway. With increased complexity and scale benefits the size of refineries has become bigger over time. Depending on its complexity refineries require an increasingly large amount of investments to construct and often takes up to 5 years to build. Little of the refining capacity is located in the OPEC countries. Given the large investments required the plants have tended to be built in stable areas close to large consumer nations. In 2014 Asia Pacific sat on 34 percent of the refining capacity, Europe / Eurasia 25 percent and North America 22 percent. Although there are vast numbers of independent refiners the largest refining capacity still resides with the NOCs and IOCs. The top 5 players are Exxon, Royal Dutch Shell, Sinopec, BP and Saudi Arabian Oil Company. The world's largest refinery plants are listed below.

Picture 7.20. The World's Largest Refineries

Name of Refinery	Location	Barrels per Day
Royal Shell Company (RSC)	South Korea	1,690,000
Reliance Refinery	Reliance, (Gujarth, India)	1,240,000
Paraguana Refinery Complex (PDVSA)	Paraguana, Falcon, Venezuela	940,000
GS Caltex Yeosu Refinery (GS Caltex)	Yeosu, South Korea	730,000
S-Oil Onsan Refinery (S-Oil)	Ulsan, South Korea	670,000
ExxonMobil	Singapore	605,000
Port Arthur Refinery (Motiva Enterprises)	Port Arthur, Texas, USA	600,250
Baytown Refinery (ExxonMobil)	Baytown, TX, USA	560,500
Ras Tanura Refinery (Saudi Aramco)	Saudi Arabia	550,000
Baton Rouge Refinery (ExxonMobil)	Baton Rouge, LA, USA	502,500
St. Croix Refinery (HOVENSA)	US Virgin Islands	494,000
YASREF (Yanbu Aramco Sinopec Refinery)	Yanbu, Saudi Arabia	400,000
Motor Oil Hellas (Corinth Refinery)	Corinth, Greece	380,000

Source: EIA and Pemex through Wikipedia

A big boat

It's a slight misnomer to say that the largest refinery is in South Korea – it is in the waters between Asia and Australia. Shell's Prelude is the world's largest ship designed to withstand category 5 cyclones. While the hull was launched in 2013, the refinery itself and the ship's LNG plant are still under construction and it is intended to produce LNG, condensate and liquefied petroleum gas.

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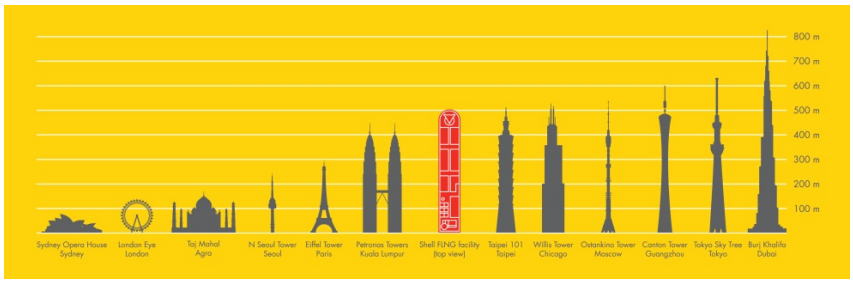
Picture 7.21. The World's Largest Ship: Shell's Prelude



Source: wonderfulengineering.com

Other mid- and downstream

MLP – Master Limited Partnerships

There are a number of independent companies transporting oil and gas through pipelines and by ship tankers. In US midstream so called Master Limited Partnerships (MLPs) have been an integral part of the shale revolution and funding has been ample. These companies build and operate for example pipelines with a "toll road" business model. They take a fee for handling a certain volume of their client's products. Since they don't own the commodities they don't take on the price risk. The legal structure is very similar to that in private equity and includes a decision making general partner and a number of limited partners that fund the investments. Future rewards are split between GPs and LPs. The LPs ownership in the MLP can then be listed so there are a number of investable MLPs in the US.

GP – General Partner

LP – Limited Partner

Retail

In the downstream retail part of the value chain gasoline, diesel, natural gas etc. are seen as a commodity with low differentiation and price pressure as results. Add to this political sensitivity and environmental legislation and the prospects of managing a chain of petrol stations becomes less exiting. Some fuels see high and constantly changing excise taxes while other fuels receive subsidies that also change. Since investments in infrastructure has to be made for selling different fuels the constant changes in taxes and subsidies pose a serious headache. Gasoline and diesel are sold by a number of retail chains around the world and by supermarkets and others. Once the retail chains were predominantly owned by the oil majors but today they have generally divested this part of the business. We will not discuss the retail part of the oil and gas value chain further.

OPEC Members

- Algeria
- Angola
- Ecuador
- Iran
- Iraq
- Kuwait
- Libya
- Nigeria
- Qatar
- Saudi Arabia
- United Arab Emirates
- Venezuela

Organization of Petroleum Exporting Countries

The oil and gas arena doesn't only contain companies. A number of organizations play crucial roles; no one more so than the Organization of Petroleum Exporting Countries, or OPEC for short. OPEC was founded in Baghdad in 1960 and article 2 of its statures reads "The principal aim of the Organization shall be the coordination and unification of the petroleum policies of the Member Countries and the determination of the best means for safeguarding their interest, individually and collectively." In short it is a production cartel aiming to keep the long term oil market price higher than what would otherwise be by withholding oil from production. The mechanism

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to do this has since 1982 been allocation of maximum production quotas between the OPEC members. Today's 12 member countries are Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela. Gabon terminated its membership in 1995 and Indonesia suspended theirs in 2009.

41% of production

The problem for OPEC is that they have never had control over more than half of the global oil production and the adherence from the individual OPEC countries in not overproducing in relation to their OPEC quotas has at times been lax. In 2014 OPEC stood for 41 percent of global oil production according to BP's estimates which includes shale oil, oil sands and NGLs but excludes liquids from biomass or coal. Collusion among competitors is always hard as there exists a free rider problem. If all the other parties apart from me hold back on their production this will create a double whammy for me as I benefit from the higher prices and my continued high volumes. However, if every country thinks the same there will be no price hike as volumes will not go down.

Saudi Arabia the swing producer

The call on OPEC

In general non-OPEC countries produce at full capacity as long as it is profitable and Saudi Arabia has, despite often being the low cost producer, taken the role of being the swing producer, adjusting its volumes to keep prices high to the benefit of the oil producing countries. The yearly production volumes that are expected to be needed after deducting the non-OPEC production from the expected demand is called "the call on OPEC". Up until last year the volume change in the call on OPEC has correlated well with changes in the oil price.

OPEC spare capacity

OPEC is capable to answer this call as they most of the time withhold existing supply from the market creating spare capacity, i.e. oil that could be produced but is offline. Saudi Arabia has historically held the most spare capacity volumes. The official definition of this spare capacity is what can be brought on line within 30 days and sustained for more than 90 days. Anticipated spare capacity levels effect the spot price of crude oil. The spare capacity today is relatively low at about 3 percent of global demand given the high production pace of the OPEC countries last year.

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7.5 The Production Chain

E&P – Exploration & Production
F&D – Finding & Development

Production of oil starts with finding oil. Exploration for and production of oil is often abbreviated simply as E&P (E&P – Exploration and Production). To find oil you need to know where to look. The first phase of E&P is Finding and Development (F&D).

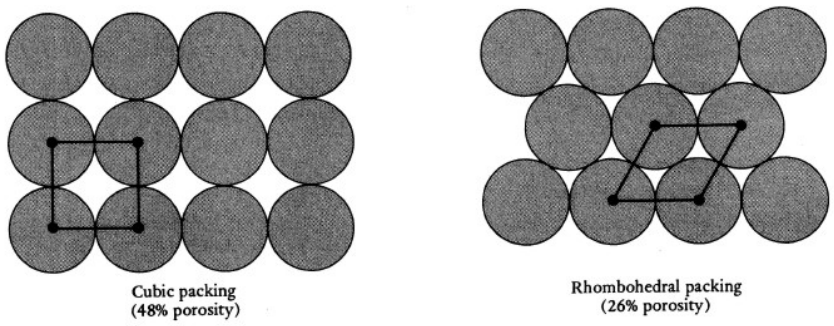
Exploration

Oil is often by the layman pictured as existing in underground lakes. This is not the case. Oil is contained inside sedimentary rock - as opposed to igneous and metamorphic rock. Sedimentary rock is composed of mechanically broken down material of earlier eroded rocks. The previously broken down material has then at some time during the earth's development ended underground and the pressure and heat created new rock. What is special with sedimentary rock like for example sandstone, limestone, siltstone and shale is that it has a high porosity.

Porosity – storage capacity of a rock

Porosity can be seen as the storage capacity of a rock. With larger voids between the rock's solid materials the storage capacity of it increases. For perfect spheres packed exactly on top on each other in layers in a container the empty space between the spheres equals 48 percent of the total volume. In this case pore spaces, i.e. the void between the materials allows the rock to contain almost 50 percent fluids, like oil. Pack the solid material differently or mix in other shapes and sizes and the porosity goes down. For sandstone a porosity of at least 18 percent is required for an oil reservoir to be economically viable and 12 percent is required for a gas reservoir.

Picture 7.22. Porosity of spheres



Source: spec2000.net

Permeability – degree of connectivity between pore spaces measured in millidarcy (md)

Sedimentary rocks not only differ in porosity but also in permeability, which is the degree of connectivity between pore spaces. Permeability is measured in millidarcys (md) after the French water department engineer Henri Darcy – not Jane Austen's Mr. Darcy - and a higher number means better connectivity. Shale and mudstone that are rock made from clay rather than from gravel and sand tend to settle in layers with less connection between them and by this trapping whatever is in the empty spaces.

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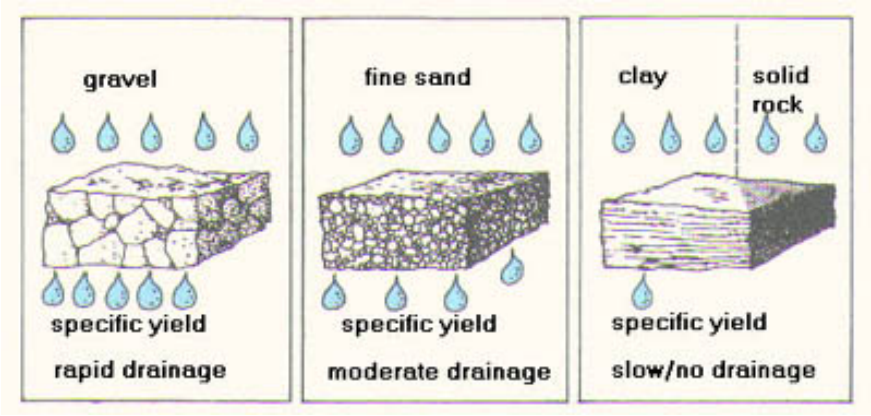
Shale and mudstone account for about 2/3 of the world's sedimentary rocks. A reservoir with lower permeability than 5 md is called tight and production will be difficult.

Picture 7.23. Permeability



Source: kalkaskacountry.net

Light hydrogens rise to the surface…

…but sometimes get trapped

There is a constant flow of fluids in permeable rocks. Most of it is water. Kerogen is a solid but the subsequently created hydrocarbons are lighter than water. This means that they rise up from where they formed, called the source rock, through porous rocks towards the earth's surface. In most cases the hydrocarbons reach the surface and are either metabolized by bacteria in nature or oxidized by the contact with oxygen in the air. However, now and then oil and gas gets trapped by a layer of impermeable rock sealing off the continued journey to the surface. These three dimensional traps are often caused by unconformities like foldings, faultings and various disruptions caused by salt domes. Geologists who look for oil often search for signs of these unconformities in the rock. In the picture below a number of traps are shown with the source rock, the reservoir rock containing the oil and gas and the seal rock. The most common traps are so called domes or anticlines. Note how the lighter gaseous hydrocarbons end up on top of the oil. The reservoir rock often contains the heavier substance water below the hydrocarbons. A reservoir is in this respect defined as a cohesive geological structure containing hydrocarbons.

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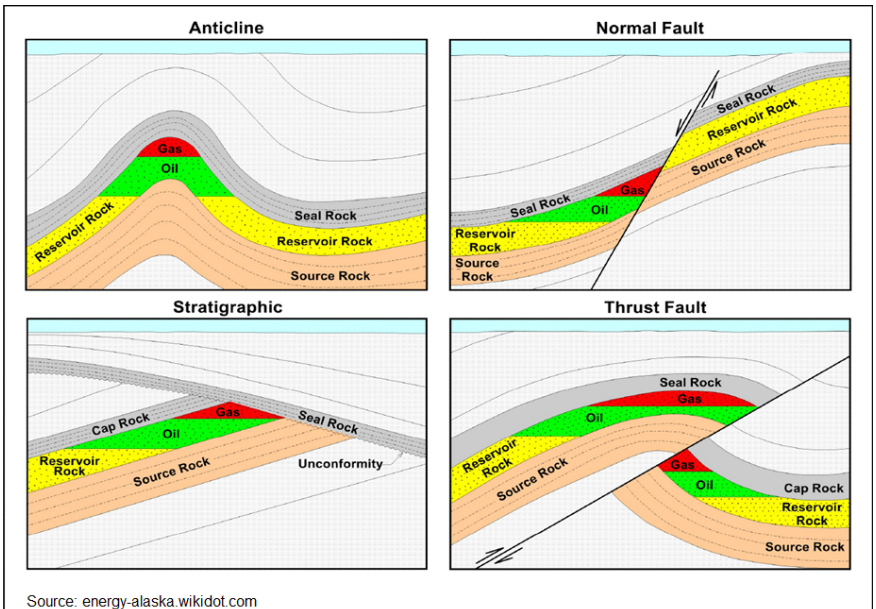
Picture 7.24. Types of Oil Traps

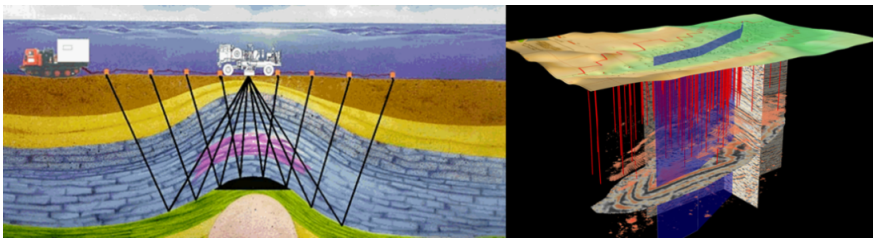


Source: energy-alaska.wikidot.com

Seismic technology

The dominant method to create maps over potential reservoirs is through seismic technology. With a device that releases a shock wave trough the ground or the water and a number of spread out sensors which measure the rebounding signals from various angels and can differentiate between the acoustics of different materials, a three dimensional picture of the rock and the possible oil field can be built.

Picture 7.25. Seismic technology and 3D-map of oil field



Source: thegascompany.blogspot.com (left) and dgi.com (right)

The probability of geologic success requires a source rock, a reservoir rock, a seal rock and a working dynamic system where the rocks can interact. By Chevron expressed as:

$$P_g = P_{source} * P_{reservoir} * P_{trap} * P_{dynamics}$$

In situ – Latin for "on-site"

All this analysis and work is however just a prelude to generating in situ data. It's time to drill.

Land rights

Now, companies can't just go around drilling wherever they want. Someone owns the ground they want to get access to. In most areas apart from the US and Canada the government owns the underground minerals of a country irrespective of who owns the surface land or the water. In North America the

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surface land owner also owns the mineral rights underground (apart from offshore areas that are owned by the costal state or federal government). Irrespective of who the owner is a deal has to be struck between the oil explorer and the owner. In the US this is a direct negotiation that often have relatively short lead times and where the negations often start with standard lease agreements that get tweaked at the edges.

Outside of North America the process of oil exploration is generally one where the government sets up a process of competitive bidding among several companies. Prior to the bidding the government will have divided an area of land of offshore water into a number of blocks. Companies bid on the right to explore this area of land or water. The right to the area can range from 3 years to 30 years depending on the type of project. Often companies join up in consortiums in the bidding to spread costs and risk. The types of commercial agreement that the government sets up varies.

A play
A lead
A prospect
Spudding

The jargon around the process can sometimes be a bit excluding. Investing to find oil is called “a play” and the geological feature of interest is known as “a lead”. After the rights have been won and the company can drill for oil it’s called “a prospect”. Leases can be of several types. A Wildcat Lease refers to tracts of land whose prospects are not well known, a Development Sale refers to releasing a previous lease because the previous holder for some reason was ousted and a Drainage Sale is the lease for tracts of land in which oil or gas has been found. The very start of drilling a new well is called spudding (“spudde” = short knife).

At the same time as the state wants to maximize its revenues, it also wants to see local investments and employment but it must let the E&P-companies that show interest in the leases retain sufficient profits to attract quality bidders. The IOC is motivated to negotiate a very comprehensive and detailed deal since when the investments have been done it is in effect locked-in bearing all the risks. Included in this are so called stabilization clauses that attempt – sometimes in vain - to freeze the laws around oil production during the duration of the project and by this secure the original terms of the contract.

Royalty/tax system vs
Production Sharing Agreement (PSA)

The terms, conditions, fixed fees and percentage splits can be varied in a multitude of ways. Two main types of deals exist. With a royalty/tax system the IOC takes position and owns the oil and gives the state a cut of the money earned. With a production sharing agreement (PSA) the government owns the oil but the IOC extracts it. When the IOC sells the oil they get a cut of the profits (or of the oil). In reality the difference might be negligible as the so called take of the government can be both higher and lower in any of the two models as is shown in the picture below. In both systems there is a deduction for the IOCs costs, a so called uplift that is meant to stimulate production. In some contracts the percentage points are not fixed over the produced volume but instead the government gets a progressively larger take the larger the volume produced.

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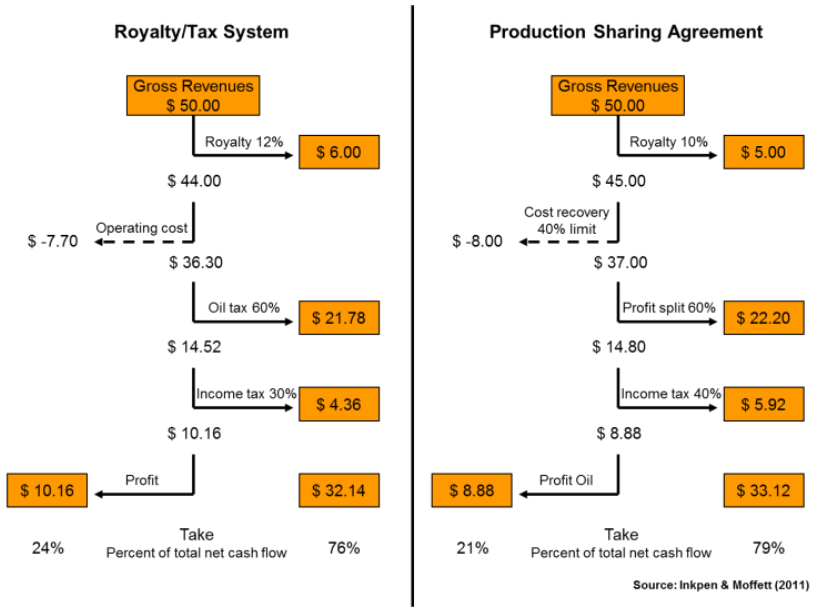
Picture 7.26. Types of Lease Contracts



Singing bonuses

In addition to the above systems there might be added contractual features. Signature bonuses are occasional up-front payments from the IOC to the state for getting the contract. These are at times deductible in income tax and withholding tax calculations of the lease. Over the years there have been a number of corruption scandals concerning signature bonuses which have reached news media - despite that they are confidential according to contract. For example, in 2000 Marathon oil paid a signature bonus of $ 13.7 million that according to press was allegedly immediately rerouted from a Jersey bank to the bank accounts of a number of Angolan ministers. Pressure from international corruption activists and also from the IOCs (who want to pay as little as possible) to end this practice has so far been less effective.

Operator handles drilling and production

Even after rights has been bid for and won, new alliances will form. If a discovery is made from a wildcat hole but it turns out that the reservoir expands into a neighboring block and the hydrocarbon findings might be relatively small per block; then it would be a costly waste that both the rights holders drilled in the same reservoir. Better then to negotiate terms, pool the ownership interests and let one of the parties, “the operator”, handle the drilling and production for an agreed compensation. Due to the many uncertainties and to the different interests and financial position of exploration companies the negotiations can be hard. Since drilling for oil requires a number of decisions where the parties can have different opinions on the right way to move forward, the contracts have to balance the right for one party to a times opt out from making certain investments with an appropriately high reward for the party who dared to make the investment that turned out to be successful.

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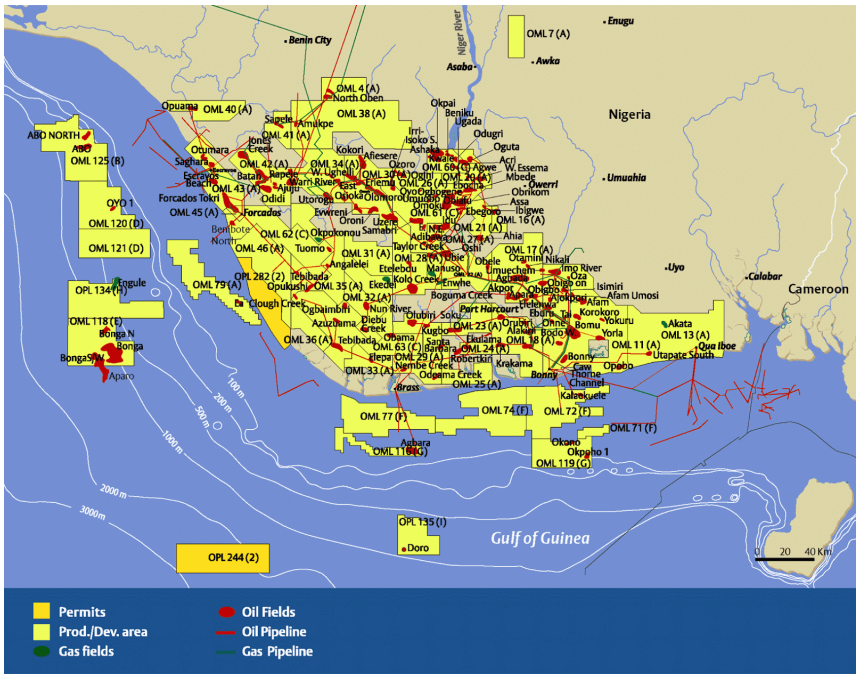
Picture 7.27. Offshore and onshore blocks in Nigeria



Source: crudeoildaily.com

Sometimes when companies want to participate in an investment but don't have the means (or cannot endure the full risk of failure), they sell a part of their ownership in the block and bring in another party in the consortium. Oil exploration is a risky business and project costs have been rising. Partnering to spread risks has grown in volumes. A very common practice is the sale of an interest in exploration permits to a firm that invests in the project and potentially also takes part in the exploration and development. From the original leaseholder this is called farm-out and is often used by small firms to raise capital and from the point of view of the new partner it is called farm-in and large firms that wish to gain access to new projects often do it.

Farm-out

Farm-in

There are further technical reasons for cooperation. There is in theory an optimal way to develop a reservoir to maximize its output. If a reservoir is split into several blocks the risk is that the operator of each block will maximize his own output without regard to the total production that then will turn out to be lower. In a process called unitization all the concerned parties consolidate their holdings to increase their total production.

Unitization

In principle drilling has been done in a similar way for a very long time. After a break-through at the Spindletop field in 1900, drilling for oil is nearly always done by rotating a drill bit on a shaft, pretty much similar to the DIY:er drilling a hole in his wall at home. The rotary drill rig contains a number of parts. The mast or derrik (# 14 in the picture) on a land based or on an offshore rig gives a frame for whatever needs to be lowered into the hole with the help of a hoisting system (#12). There is a drilling mud system (#1 through 4) and an engine (#5) to drive the drill and rotate the drill string (#25) with the help of what's called a kelly (#19) that is fitted into a rotary table (#20). Further, there

The drilling rig

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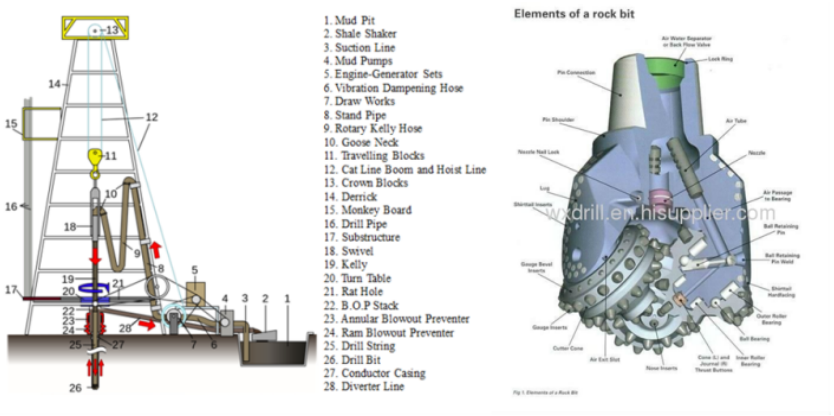
is casing around the walls of the hole (#27) and blowout prevention equipment (#22 through 24) to hinder pressurized gas and liquids from escaping the well. The blowout preventers are basically rams that close the hole if liquids uncontrollably rise to the surface (failed miserably for BP/Transocean at the Macondo blowout 2010). Onshore the BOP stack is placed under the rig floor. Offshore it is usually placed on the ocean bottom. Furthest down in the underground the drill bit (#26) is at work pulverizing rock. The drill bit to the right in the picture below is called a tricone for obvious reasons.

Picture 7.28. Rotary drilling rig and drill bit



Source: afforedablefrc.wordpress.com (left) and wxdrill.en.hisupplier.com (right)

The derrik must be able to handle the weight of the casing and the drill string so the deeper the hole, the larger the mast. When the drill bit needs replacing the drill string is withdrawn with the help of a number of blocks (#11 and 13 above) and then lowered again. This process is known as making a (round) trip. What's the purpose of filling the drill hole with mud? Several actually: by keeping the right density and viscosity it equalizes the earth's pressure and prevents the hole from collapsing before permanent cement casing can be applied, the mud lubricates and cools the drill bit and importantly by rotating the mud in and out of the hole the rock cuttings from the drillings are removed. The drilling mud is prepared by a mud engineer, known as the hoghead. Drilling speeds are about 30 meters per hour so it's a long and error prone process to drill an oil well.

Hoghead

About a third of oil production comes from offshore wells and the share is increasing. Drilling offshore is in principle the same as drilling onshore. The surroundings do however add to the strain, a riser pipe extends from the BOP at the seafloor to the platform and the mud return line is separate from the riser pipe to lower the bottomhole pressure. To allow for the movement of the offshore platform the top and the bottom of the riser have flexible joints with hydraulic compensators at the top. Another challenge is to prevent viscosity of the oil from dropping as it's pumped up through the riser in the cold water. The crude is kept warm by insulating and heating the tubing. Over time oil exploration has gradually moved to deeper waters. Drilling up to 1,000 feet (about 300 meters) is known as shallow water drilling, between 1,000 and

Offshore drilling

Drilling

- Shallow water drilling
- Deep water drilling
- Ultra-deep water drilling

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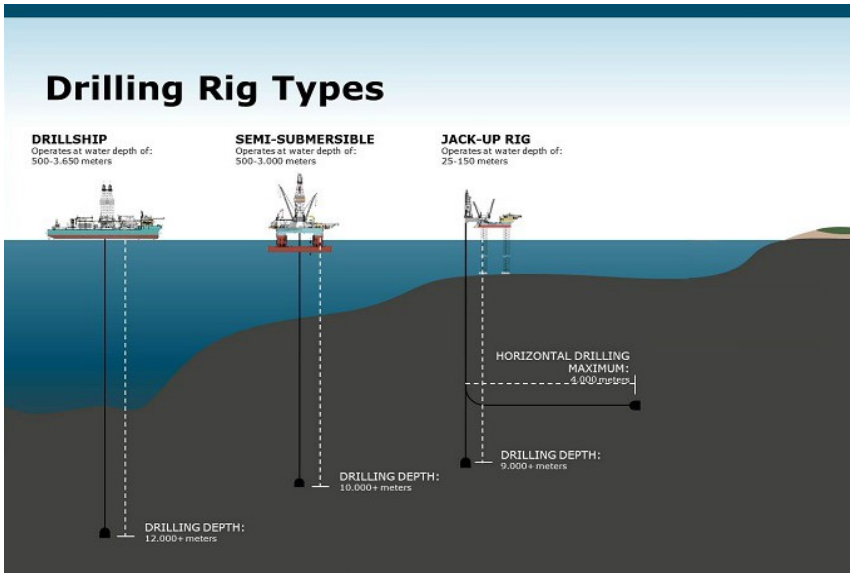
2,500 feet (about 760 meters) deep water drilling and deeper than that up to 12,000 feet (ca 3.7 km) as ultra-deep water drilling.

Drilling rigs

- Jack-ups
- Semi-submersibles
- Drillships

Depending on the depth of the water different types of drilling rigs are used. At water depths of 25 to 150 meters jack-ups are the most common rigs, at 500 to 3,000 meters semi-submersibles are the usual choice and for even deeper waters drillships do the work. Once a floating jack-up is in position it lowers its legs to the sea floor which raises the deck out of the water. Floating vessels are attached to the sea bed using cables and anchors. Further, there are so called dynamically positioned (DP) ships that use GPS satellite navigation and thrusters to keep the vessel in position.

Picture 7.29. Offshore drilling rigs



Source: maerskdrilling.com

Rig vs platform

Offshore production

SURF – Subsea Umbilicals Riser and Flowlines

FPSO – Floating Production, Storage and Offloading vessel

FDPSO – Floating, Drilling, Production, Storage and Offloading vessel

Drilling rigs operate 24 hours a day in three 8 hours shifts. On a rig or a platform the floor is called the deck and the structures on the deck are called topside. The pontoons of a semi-submersible are called its hull. To protect from waves the deck is about 15 to 20 meters above sea level. The offshore production of oil and gas is done from an oil platform. The drilling rig and the production platform can be the same but generally they are not. Apart from the oil drilling or production equipment it contains the accommodation for the operating personnel, cranes for equipment handling and helipad(s). In offshore production, parts of the equipment called SURF (subsea umbilicals riser and flowlines) will be placed on the sea floor. These subsea production systems are used to develop reservoirs, or parts of reservoirs, satellite developments, infill drilling etc. which require drilling of wells from more than one location. The production oil platforms have different names based upon what they perform. FPSO is short for floating production, storage and offloading vessel. A FDPSO adds drilling rig capabilities and is a production chain of its own capable of drilling the well, producing the oil, storing the oil and offloading it to oil tankers for further transport.

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The drilling provides the ultimate estimate of the production capacity of a geological trap that has been deemed promising. Using sensors attached to the drill string the hydrocarbon content of a reservoir can be estimated. The process has to try to assess several parameters such as the hydrocarbon saturation of fluids, the volume of a reservoir and the porosity of the rock to come to a conclusion. With a so called drillstream test letting the hydrocarbons temporarily flow freely the pressure of the reservoir can be tested. Both the total oil in place and/or gas in place and the ultimate recovery rate (or recovery factor, RF) are critical to estimate and the pressure of the reservoir is critical for the later. Thanks to new technology the ratio of unsuccessful vs successful wildcat holes has dropped significantly over the last few decades but it is still only about 3:1.

Recovery rate or recovery factor (RF)

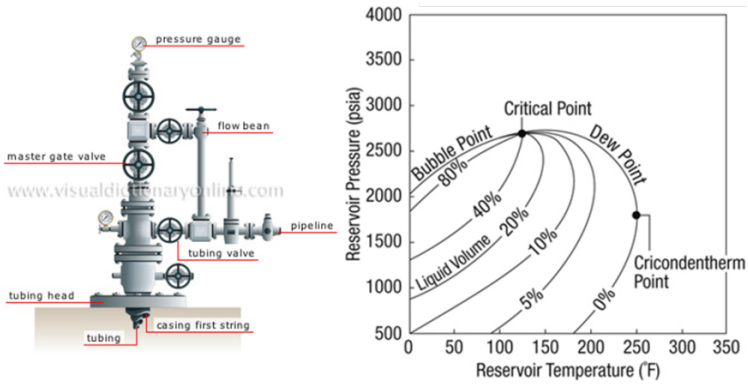
Production

So now we know, the hole is either dry - a duster - or it contains hydrocarbons but too little is recoverable for production to be economical or enough oil and gas is present to motivate production. In the latter case the hole has to be cased, otherwise it is plugged with a cement plug (P&A, plugging and abandonment). The wall of the hole that is going into production is cemented to ensure its structure and hinder pollution. The deeper down in the well each successive string of casing runs inside the previous string giving the production casing at the bottom of the well the smallest diameter of about 10 to 20 centimeters. Later, further production tubing will run inside the cement casing. A wellhead is placed on top of the casing and a number of valves are attached to it to facilitate production from the well. Since there are often a large number of valves attached on top of each other the stack is called a Christmas three. If it's placed onshore or on an oil platform the valves are called a dry tree, if it's placed on the bottom of the sea it's called a wet tree. Wet trees are encased in solid steel boxes to protect from the underwater environment. To commence production the final step of constructing the well is to perforate the production casing, i.e. a number of holes are blasted open in the casing to allow for the flow of hydrocarbons to the surface.

P&A – Plugging and abandonment

Christmas tree!

Picture 7.30. A different type of Christmas tree and a phase diagram



Source: visual.marriam-webster.com (left) and informit.com (right)

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FID – Final Investment Decision

When a company commits to try to recover oil or gas it's called the final investment decision (FID). The decision is taken on a combination of the estimated net present value of the well considering expected recovered volumes, expected prices and operating costs and also the risks associated with the development. Risk assessment looks to project risks given the geography and other factors, such as technological risks if using leading edge technologies, potential partner issues, environmental risks, corruption risks, political risks such as government interference or expropriation, currency convertibility and risks from instability of the local economy.

Finding & development costs
Lifting costs
Government taxes

Oil fields and especially gas fields can be in service for some 40 years or more and production resembles capital intensive manufacturing in that the focus is on maximizing output and minimizing costs and investments. Costs pre-production are called finding costs and development costs. Costs after operations have been initiated are the direct lifting costs and the production taxes due to the government which owns the land.

Natural flow

GOR – Gas-oil-ratio

The first phase of production is driven by the natural flow of the well. The pressure underground is higher than at the surface. Opening a pathway between the two will cause the hydrocarbons to migrate from the trap to the surface. When the underground pressure is high enough this can result in a gusher (or blowout) when the drilling reaches the reservoir rock, making the BOP stack critical. As the reservoir gradually is emptied during production the pressure drops and this also affects the hydrocarbon molecules in the well. If nothing replaces the fluids as the reservoir is depleted the production rate will drop. Every reservoir has its own composition and will react differently to being emptied of hydrocarbons. The so called oil and gas phase diagram above to the right tries to map how the well will produce different mixes of oil versus gas as production continues over time (the gas-oil-ratio, GOR) and the pressure of the reservoir goes down. Above the bubble point only oil will be produced, below there will be a gaseous content and below the drew-line only gas is produced. A gas well will often stay in this natural state driven by pressure differences for a very long time.

Pressure drop

Why is there a difference between oil in place and the amount of oil that is recoverable? The main effect is the drop of the pressure but there are other causes. Remember, all the hydrocarbon content is a slush of millions of different hydrocarbon molecules. When the pressure drops in the reservoir, gas around the reservoir condensates and separates from the crude oil. Since the gas flows easier through the reservoir rock it crowds out the liquids and causes a large amount of the oil being left in the reservoir without enough natural pressure to bring it to the surface. Similarly, any oil reservoir's fluids contain both oil and up to 20 percent water. Depending on the relative amount of oil versus water the one with the largest proportion will flow faster and crowd out the other, a phenomenon called relative permeability. Hence, when the oil is depleted by a certain amount, water will start to crowd out the flow of oil leaving the oil stuck in the rock.

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Pump the oil

The easiest way to continue producing after the natural flow has become to faint is to pump the oil and water mix out of the ground. The sucker rods, or "nodding donkey's", seen on many oil fields are pumps. The ability to pump oil out of the reservoir is however limited and most pumps simply pump oil up the well. Instead, if deemed economical, secondary and tertiary recovery now starts. There are a number of methods to enhance the recovery. In waterflooding water is pumped in adjacent to the oil in the reservoir making the water transcend into the well maintaining the pressure on the oil. As the oil is pressed in a direction it is at times a good idea to drill a second set of holes in the reservoir. However, some oil is too heavy to move and with °APIs lower than around 17 (remember, lower °APIs means higher relative gravity, aka weight) the injected water will tend to move around the oil. One solution is to reduce the viscosity, the resistance to flow, of the oil. By periodically injecting hot steam from a neighboring hole the flow of the oil increases, thus increasing production.

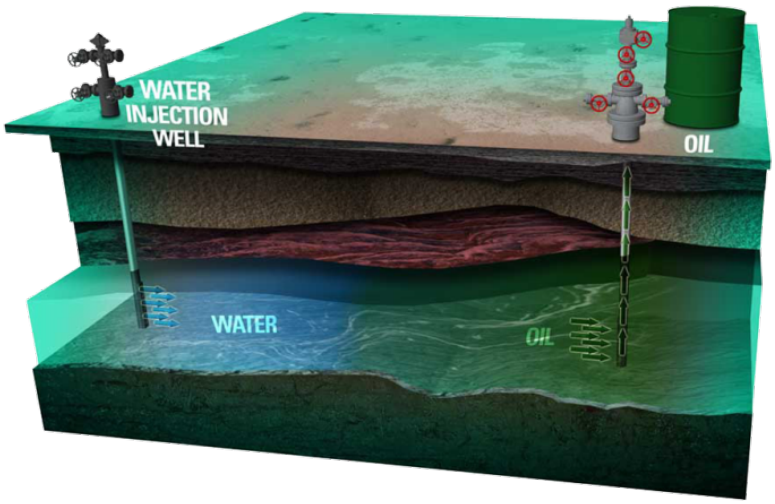
Waterflooding

Heat the oil

Gas injection

In addition to injecting water in the reservoir, gases can be injected to keep the pressure up and the oil flowing. Often the injected gas has been CO_2 which has the desirable side effect to reduce the amount of this gas in the atmosphere. As CO_2 mixes with the oil the oil swells and detaches itself from the rock walls and flows to the well. One additional method focused on increasing the permeability of the reservoir is hydraulic fracturing that we will cover when discussing gas.

Picture 7.31. Waterflooding Recovery



Source: segiusa.com

MER – Maximum efficient rate

To optimize the recovery ratio of a reservoir it is important to keep the natural drive as long as possible and there exists an optimal speed of recovering the oil called maximum efficient rate (MER) that keeps the pressure and maximizes the amount of extracted hydrocarbons.

Technology is probably the most constantly underestimated force in the field of oil and gas. Time and again through history exploration and production technology has been said to have reached the end of the road only to deliver a

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major breakthrough not long thereafter vastly expanding capabilities and by this economic reserves. Increasing computer processing power has meant much more exact seismic mapping using 3-D technologies, horizontal drilling has lead to an expansion of resource basins being accessed and CAD/CAM-technologies has meant that offshore platforms can be designed, tested and redesigned to correct for mistakes even before leaving the computer screen. Billions of barrels of oil that previously weren't technically or economically accessible become part of reserves at each technological breakthrough. The natural flow gives a recovery rate of about 15 percent. Add waterflooding and this takes the recovery rate to about 40 percent. With CO_2 injection and other enhanced recovery methods the rate increases to 60 percent and in rare instances up to 80 percent. The average global recovery rate is increasing over time. Today it's about 40 percent.

Recovery rate 40%

Before the hydrocarbons can be sold to intermediate customers like refineries an amount of housekeeping is called for. All gases must be separated from liquids, basic sediment and water (BS&W) must be separated from the oil. In some cases the water and oil has formed an emulsion and the liquid has to be heated to separate out the water. The water can be re-used for injection in the well to keep the pressure. If this is not possible all contaminants must be removed before releasing it into the sea offshore or else it must be transported to a water-disposal facility.

BS&W – Basic sediment and water

Refining

Refining
1. Separation
2. Conversion
3. Treatment
4. Blending

The crude oil and the gas produced from wells are not products that are sellable to end customers. The oil and gas have to be converted to what the customers want to buy. This is done in refineries that use the crude oil as their feedstock. The processes in a refinery can be divided into steps: 1) separation, 2) conversion, 3) treatment and 4) blending.

Separation is what it sounds like. The crude oil has to be separated from the remaining water and it has to be desalted. Further, hydrocarbons of different density are to be separated from each other through distillation.

A liquid like water contains one type of molecule containing two hydrogen atoms and one oxygen atom - H_2O. All water that reaches 100 °C boils and becomes a gas and if the gas is held at this temperature it will not evaporate into a liquid. Crude oil is not one type of molecule but millions. Each of these molecules have their own boiling temperature. Generally the higher the mix of carbon atoms the higher the boiling temperature. For convenience the molecules are lumped into groups called fractions. Thus, fractions or cuts are the name for all compounds that boil between any two temperatures called cut-points. This is what's shown in the picture below.

Fractions or cuts

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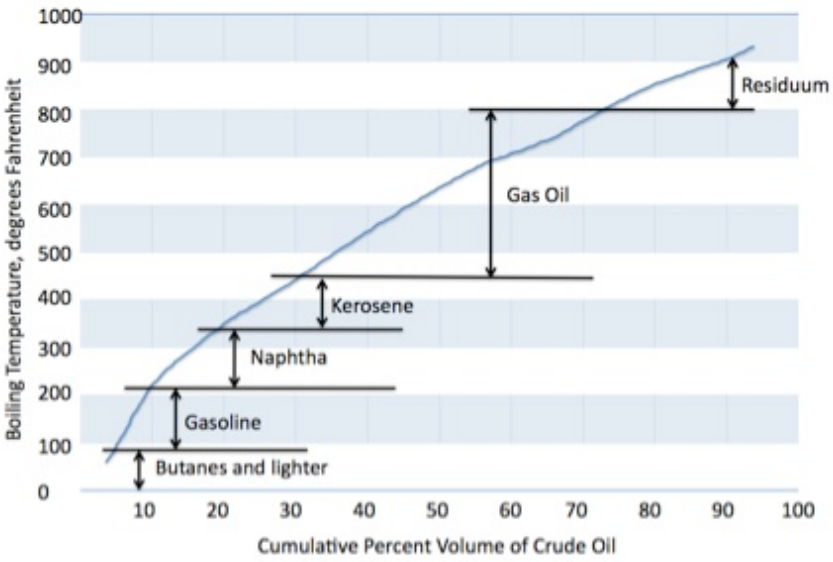
Picture 7.32. Crude Oil Distillation Curve



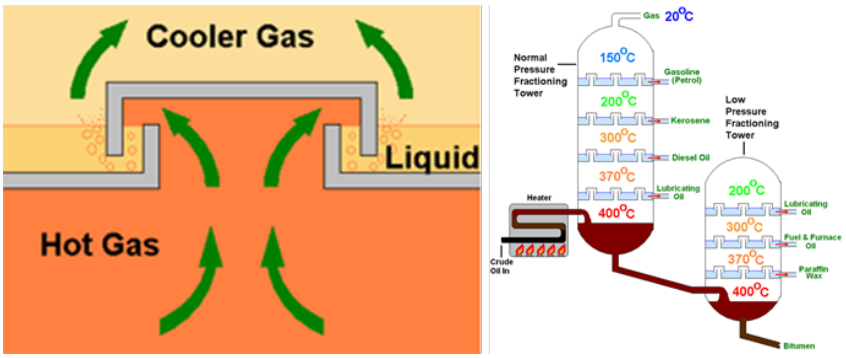
Source: pavementinterative.org

Distilling

Vacuum flashing

The separation of different hydrocarbons is done through a distillation process where the crude oil is pumped through a furnace where it's heated to a temperature of about 400 °C and becomes a gas contained in a distilling column. Inside the distillation column there are a number of trays with perforations in them called bubble caps that allow the gas to rise upwards and gradually cool and evaporate into liquids. The gas cools as the bubble caps force it to bubble through the cooler liquid on the tray. The heavier molecules cool faster while the lighter ones continue up to the next tray and by this the various cuts can be separated. The process is repeated to improve the separation. If exposed for temperatures above about 490°C the energy is enough to crack the long molecules into smaller pieces. As this is not desirable in this stage distillation is partly done in vacuum (called vacuum flashing) as this lowers the pressure on the molecules and prevents them from cracking.

Picture 7.33. Bubble Cap and Distillation Column



Source: gifsgallery.com (left), green-planet-solar-energy.com

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Cracking

The second conversion step of the process reads like a chemistry experiment where you manipulate, mix and match the chains of hydrogen and carbon atoms. There will be a large amount of hydrocarbons that have not been separated in the distillation process as the molecules are too heavy. Through so called cracking a heavier hydrocarbon is broken apart and turned into several lighter hydrocarbons. Since several molecules with the same number of atoms have higher volume than one molecule with the same number of atoms as the others combined, the volume of hydrocarbons increases in the cracking process - sometimes called refining gain (or process gain).

Thermal cracking

Cat cracking

Thermal cracking is breaking apart heavy molecules with heat and pressure. Further, by combining the heat and pressure with chemical catalysts to facilitate a reaction in a process called catalytic cracking, or cat cracking, a specific way of breaking the molecules is promoted. The end object is basically to convert heavier cuts to gasoline. In reality the process isn't that exact and a full range of hydrocarbons are created including a solid residue called coke. There is also a reverse process called alkylation where catalysts are used to combine lighter molecules into heavier ones called acrylates. Hydrocarbon molecules can in effect both be made smaller, larger and they can be re-arranged.

Cooking and hydrocracking

Inevitably there will still be amounts of heavy residue hydrocarbons left - the end of the barrel. Through cockers that crack the molecules at high temperatures and pressure with additions of extra hydrogen atoms the residue can be turned into hydrocarbons which can be used for example as blendstock in gasoline. The process of using extra hydrogen as a catalyst in the cracking process is called hydrocracking. The cocker makes all the residue go away but 30 percent of the material is turned into coke for which a use or market must be found. Fortunately, coke can be used as refinery fuel in the same way as coal.

Blend and mix ingredients

The third and fourth steps are treatment and blending. In a process called hydroprocessing hydrogen is used to remove unwanted polluting substances like sulfur, nitrogen, nickel etc. Finished products are then the result of blending different hydrocarbon cuts. Gasoline for example hasn't got high enough octane content so it is mixed with either FCC gasoline, reformate, naphtha or alkylate and so on. Refiners also add their special additives to increase the attractiveness of their products.

Refining gain

In the end the refinery has produced a number of products from the crude oil. Methane from gas refineries is marketed as the product natural gas. From the 42 gallon barrel there will be more than 42 gallons produced. This refinery gain is as noted due to the larger volume of many smaller molecules that have been created from the previous larger molecules.

The golden rule for the refinery is to maximize the amount of high value gasoline and other middle distillates like fuel oil, used for diesel and heating oil, or jet fuel. Residual fuel oil in the picture below is for example used as fuel for ocean going vessels. Bitumen is rich in asphaltene molecules and is used for making - surprise - asphalt. Gases like Ethane, Propane, Buthane and Light

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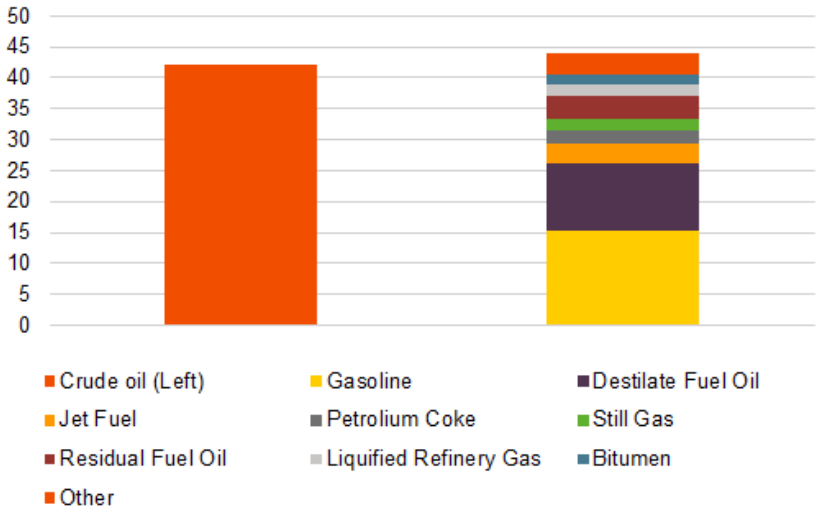
Naphta plus liquids like heavy Naphta and light Fuel Oils are the feedstock of the petrochemical industry.

Picture 7.34. Refinery Output



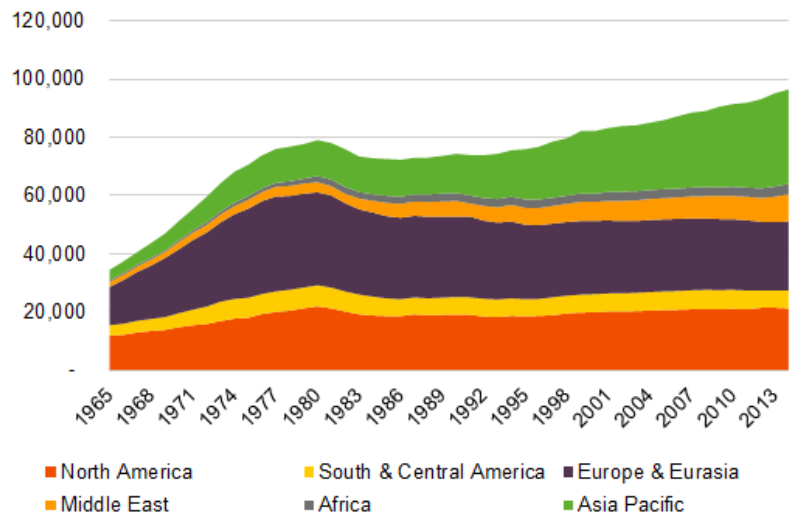
Source: EIA Data

Poor profitability

Crack spread – the margin gained from selling produced end customer products minus the input cost of crude oil

Since refining for decades was the least profitable area in the energy sector very few refineries were built until the most recent decade – instead capacity was expanded by increasing the complexity at the refineries that already existed. Despite this the global refining capacity was flat between 1980 and 1999. Since 2005 the higher crack spread and the accommodating monetary policies around the globe have stimulated investment and especially the Middle East and Asia Pacific have added capacity.

Picture 7.35. Global Oil Refining Capacity, Thousands barrels/day



Source: BP Statistical Review of World Energy 2015, Workbook

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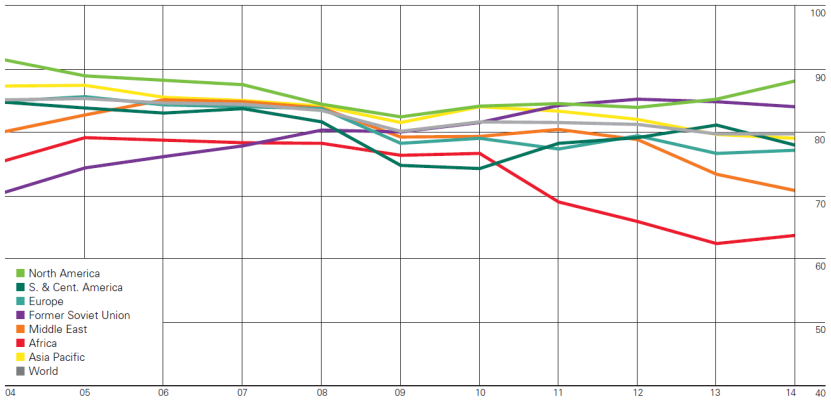
With the additions of new capacity and a slowing end product demand in 2014 the capacity utilization was 79.6 percent, its lowest rate since 1987. Refineries have grown increasingly more complex in the last few decades and all processes are not applicable to all products with the consequence that full capacity utilization is almost impossible to reach. If 95 percent is reached this should be considered as good as full capacity utilization. Not all refineries are the same. A refinery must be designed for a specific range of crude oil properties or else the build cost would be too high. Some are constructed to refine light oil or heavy oil where the latter is a much more cumbersome process but is also supported by the lower input price of heavy crude oil compared to the lighter varieties. At times utilization of some types of refineries might be significantly different than for other types.

Built for light crude or heavy crude

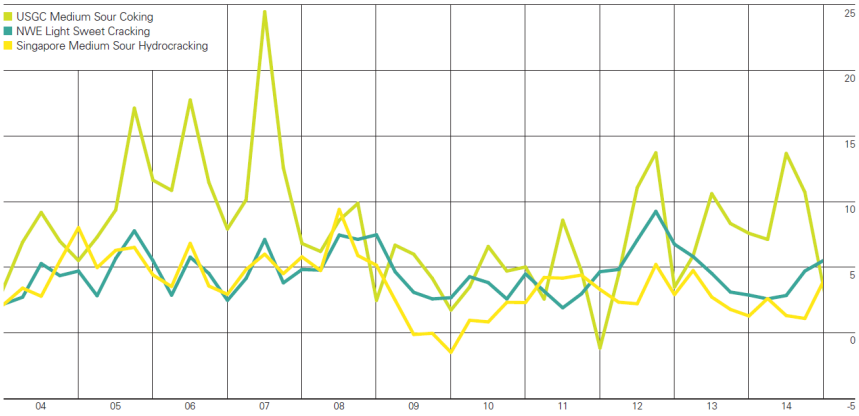
Picture 7.36. Refinery Utilization, %



Source: BP Statistical Review of World Energy 2015

In the economic boom 2004 – 2007 oil prices went up to record levels but gasoline and jet fuel prices actually rose even more. Pre-Lehman the crack margins were the best they have been for ages as refineries with new capacities could buy sour heavy crude and convert them to higher value end products. Then came the crisis.

Picture 7.37. Regional Crack Margins, USD/bbl



Source: BP Statistical Review of World Energy 2015

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Transportation and Storage

Pipelines and tanker ships

We don't all live or work next door to a refinery. The products have to be transported to the refinery and from the refinery to the end customer retailers. Larger volumes of oil are transported by pipeline or tanker ships. For longer distances oil tankers are by far the cheapest - and often the only - alternative. Smaller volumes can be transported by rail car or tank trucks.

Outage – empty depth

Innage – depth with cargo

Plimsoll mark – show full load

Wet cargo vessels can be so called clean product tankers that carry products like naphtha, gasoline etc. These are often smaller and travel shallower waters. Dirty tankers carry crude oil, residual fuel oil or bitumen and are also called black oil tankers. About half of the global oil production is transported with dirty tankers at some point of time. The hull of the vessel contains three types of tanks: the cargo tanks, the ballast tank and the slops. Rows of separated cargo tanks carry different grades of cargo. The depth of empty space that is not occupied by oil is called outage while the depth of liquid is known as innage. For a fully loaded tanker the water level rises to the Plimsoll mark, the horizontal line painted on the hull of the ship. On return trips vessels unfortunately travels empty as so called backhaul cargo is rare to find. Sea water in ballast tanks lower the ship when traveling without cargo. After discharging the cargo the cargo tanks are cleaned and the resulting mixture of water and oil is kept in so called slops.

DWT – Deadweight tonnage

DWCC – Deadweight cargo carrying capacity

Tankers

- Handy size
- Panamax
- Aframax
- Suezmax
- VLCC
- ULCC

Oil tankers are graded after the size of the vessel where petroleum products often is shipped with the smaller vessels and crude oil with the larger ones. The size is measured in deadweight tonnage (DWT), which is the displacement of water of a fully loaded ship minus the displacement of a so called lightship, i.e. one without fuel, cargo, drinking and washing water, people, temporary ballast and other variable load. Only subtracting cargo gives the measure deadweight cargo carrying capacity (DWCC). Tankers of 20,000 to 55,000 DWT are called Handy size, up to 80,000 DWT Panamax, up to 120,000 DWT Aframax, up to 180,000 DWT Suezmax and supertankers above this size are classified as Very large crude carrier (VLCC) with a maximum DWT of 320,000 and Ultra large crude carrier (ULCC) above this. The largest oil tanker as of now is the Seawise Giant with a DWT of 564,650. Supertankers are too large to pass through the Suez or the Panama canals and cannot port at many locations. Instead offshore discharging terminals are used.

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Picture 7.38. Seawise Giant

Another big boat

Source: wallstreetdaily.com

An oil tanker can have a single hull or a double hull to provide an extra safety layer between the cargo and the ocean. Out of the 20 worst tanker spills in history 19 has been with single hull ships. Since 1990 all newly built ships have to be double hull vessels and gradually as older ships are phased out single hull ships will disappear from the seas. Phasing out a ship takes time though as they often can be in service for 40 years.

Oil tankers don't operate alone. Lighter, so called barges, are used to offload oil from the larger vessels. Re-fueling of oil tankers is called bunkering and is done by smaller vessels that pull up alongside the larger ships. Danish OW Bunker that went into a well-publicized bankruptcy last year was one of the world's largest traders in bunker oil.

Worldscale

Some oil tankers are owned by the oil producers but the majority are owned by independent companies. Thus, there is an active brokerage market for chartering ships connecting those with tonnage to ship and those who own vessels. Often several cargoes have to be pooled to fill a ship. Pricing of the transport itself is generally set by a standard called Worldscale that lists a base rate price for a set of standard factors related to speed, fuel consumption, port time, canal transits etc. Then a final price is negotiated with reference to this base rate.

FOB - Free on board
CFR – Cost and freight
CIF – Cost, insurance and freight
DDP – Delivered duty paid

Standard contract terms between sellers and buyers of oil are 1) Free on board (FOB) where the sellers responsibility ends when the cargo pass the ship's rail, 2) Cost and freight (CFR) where the seller also pays for all costs to bring the cargo to the destination port minus insurance of the cargo in transition, 3) Cost, insurance and freight (CIF) as previous but insurance costs are paid by the seller and 4) Delivered duty paid (DDP) where the seller is responsible for all costs for delivering the oil to a specified destination.

Pipelines

The other main method to transport oil is through pipelines. All produced oil passes through a pipeline at some point in time. Just as in shipping, pipelines

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can be divided into black oil pipelines and clean product pipelines. In many parts of the world pipelines pass through a number of countries making them highly political and the permits to build the pipelines can require long and hard negotiations.

Long-haul fungible

Short-haul batch

Long distances are covered by long-haul lines, also called trunk lines, of large diameters up to 150 cm and with delivery points for connecting short-haul lines. Long-haul lines operate in so called fungible mode. The customer will receive the same amount of the same quality of oil or gas at the end of the pipeline as he sent in to it but it might not be the same molecules. This is in contrast to short-haul lines that usually operate in batch mode, i.e. the customer in the end receives exactly the same molecules he sent in. Short-haul pipelines can be as thin as 10 cm in diameter. Pipelines are built of steel and most are buried underground. The main wear and tear is corrosion. This is partly mitigated by applying a low voltage to the line. Further, the lines at times clog up with asphaltene and waxier hydrocarbons and have to be cleaned by devices called pigs that are sent through the pipe.

Picture 7.39. Scenic route for pipeline left but most are buried underground

Source: solarstorms.org (left) and freeportproject.org (right)

Sequencing

The hydrocarbons move through the pipeline at a rather pedestrian speed of 1 to 6 meters per second. To utilize a pipeline efficiently multiple products are sent along the same pipeline without any physical barrier between them in a process called are sequencing. Similar to oil and vinegar that is layered in a jug due to their differing density, the different density of the oil cuts flowing in the pipeline means that they only mix to a small amount. The trick is to avoid sending batches of products that are too similar right after each other. The small amount of fluids that mix is known as so called transmix and has to be reprocessed or sold as a lower quality product.

Cushing, Oklahoma

Places where pipelines meet are called hubs and if the hub is by a port it's called a marine terminal. The main pipeline hub in the US is Cushing in Oklahoma which has labeled itself the "Pipeline Crossroads of the World" despite a modest population of 8,000 persons including 1,000 prison inmates. Oil stored in Cushing tanks later flows to refineries to produce end-market products. More than 1.1 million barrels a day pass Cushing. Importantly, in the derivatives trading of WTI oil futures, Cushing functions as the place of delivery for the unlikely event of anyone actually wanting physical delivery.

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Picture 7.40. The Pipeline Crossroads of the World

Cushing – established in 1891 when Billy Ray Little built a house in the Sac & Fox Reservation and established his claim on the land. The town saw a short oil boom between 1912 and 1916

Source: politico.com

Depending on the distance the transportation cost can be a fair part of the price paid for the crude oil or the petroleum etc. The picture below shows estimated US pipeline costs.

Picture 7.41. Crude Flows and Costs

Source: VLO

Storage

The oil cannot be on the move all the time. Now and then it has to be stored. There are seasonal shifts in demand, some customers want to have a buffer for supply disruptions, governments want reserves for energy security reasons and expectations of higher future prices also stimulates speculators holding on to oil to sell it later. Hydrocarbons are stored in underground spaces, above ground tanks and tanker ships. Underground storage is predominately used for natural gas.

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Tanks

- Atmospheric tanks
- Low pressure tanks
- Pressure vessels

Overground tanks are found in clusters, so called tank farms, adjacent to production sites, refineries, pipeline hubs like Cushing and marine ports. The tanks are of carbon steel painted white to reduce heat and by this evaporation of oil. Tanks are of three types: 1) Atmospheric tanks have fixed roofs and store non-volatile products like oil at normal pressure. 2) Low pressure tanks have floating roofs to prevent evaporation and due to the flexibility they can also be used to store more volatile products like gasoline. The floating roof can be internal under a second fixed roof or it can be external. To prevent it from sinking into the oil the floating roof rests on pontoons. 3) Finally, pressure vessels are used to store materials like propane or butane which has to be kept under high pressure. For safety reasons these tanks are often situated at the outer end of tank farms.

Picture 7.42. External Floating Roof Tank

floating-roof tank

Source: visual.marriam-webster.com

Storage on tanker ships

Further, tanker ships can be used for storage of oil rather than for transport. This is usually the most expensive form of storage and only used when other options are closed.

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7.6 The Oil Price

…and the short run could be years…

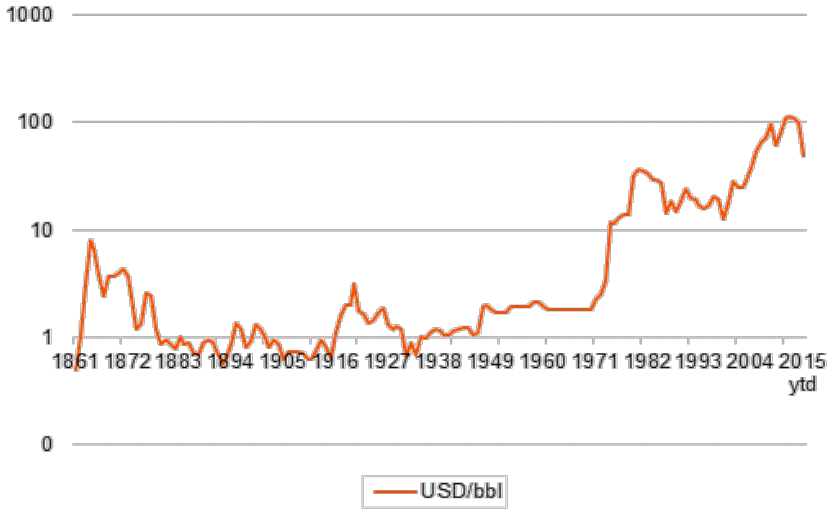
"It's hard to analytically put a price on an asset that doesn't produce income. In principle, a non-perishable commodity won't be priced below the variable production cost of the highest-cost producer whose output is needed to satisfy total demand. But in reality and in the short run, strange things can happen." / Howard Marks, Oaktree Capital

"There is probably no product price that has been subject of more conjecture and predictive investment over time, with such poor results in prediction, than the price of oil." / Andrew Inkpen & Michael Moffett

3% CAGR since 1861

With a price for Brent of USD 48.46 the CAGR of the oil price has been marginally above 3 percent since 1861. The real CAGR has been 0.9 percent – not very impressive and not very indicative of the huge swings during the period. However, starting from 1973 the parallel numbers have been 6.7 percent and 2.5 percent and starting in 1998 they are 8.4 percent and 6.0 percent.

Picture 7.43. Oil Price: The Really Long-Term View (log scale)



Source: BP Statistical Review of World Energy 2015 Workbook

The Brent goose

Like many other commodities the price for oil is set by global demand meeting global supply. Since the 1980s pricing for physical delivery of oil uses benchmark pricing that references to the exchange traded spot price. The spot price is set during 24 hour (but not 24-7) trading on a number of commodities exchanges around the world where NYMEX and ICE are the largest. NYMEX mainly trades in WTI and ICE in Brent (named by Shell after the Brent goose). A specific quality of oil like say Nigerian Bonnie Light or Mexican Isthmus will sell at the benchmark price times a premium or discount specified by a formula plus benchmark freight costs. Transportation costs can as noted often be a substantial part of the purchase price for the commercial buyer.

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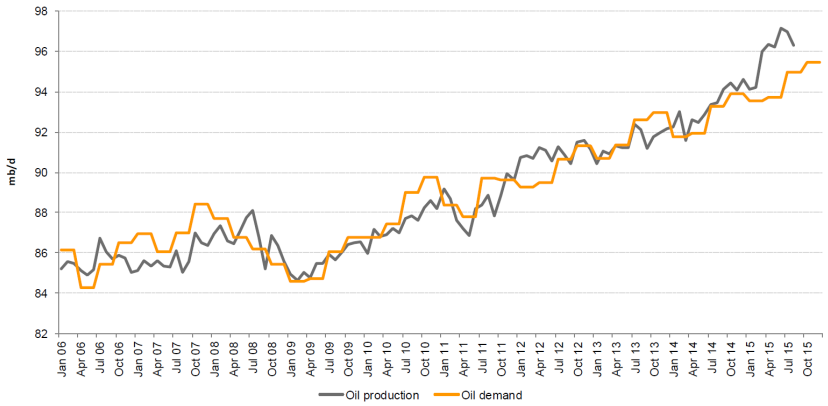
Picture 7.44. Total Global Oil Supply and Oil Demand



Source: IEA, Swedbank

Petrodollars

To foster international transparency and liquidity of the trade, oil is priced in USD - sometimes for this reason called petrodollars. The relation between USD and other currencies where oil is used then affects the price of oil. If the USD weakens then, all other things being equal, oil prices will rise in USD terms. If the USD strengthens then, all things being equal, oil prices will fall in USD terms. Hence, the oil prices rally when the USD weakens and plunge when the USD strengthens.

The Saudi swing producer…

The background to the previous 12 – 15 months dramatic fall in oil prices was the decision of Saudi Arabia that it was in their best long-term interest to curb the growth rate of North American unconventional oil. Saudi Arabia has for decades taken on the role as the swing producer of oil allowing other nations to produce at full capacity. The interesting thing with the production of shale oil is that the cost structure is totally different from conventional oil production.

…meets the US swing producer

Their upfront fixed investments are small and production can be seamlessly scaled up and down in relatively short periods of time. The risk of drilling a dry hole is low but a well has a short life span and after three years it is seldom profitable to continue production. Instead the producer moves on to the next well in a continuous and almost industrial production process. The turnover of projects is very fast compared to traditional oil production. This means that if the oil price is higher than a certain level, large volumes can be supplied and if it's below the level volumes quickly falls away. Thus, a new swing producer has emerged and this swing producer consists of hundreds of small companies that don't react to central commands from a cartel committee but to market prices.

"The call on shale"

It is now motivated to discuss "the call on US shale" instead of "the call on OPEC". You could actually say that the oil market today is experiencing free market price discovery for the first time in 40 years as OPEC, at least temporarily, has stopped working as a cartel. So by changing strategy, producing at full capacity, focusing on their market share despite a supply glut and taking the pain of a lower price Saudi Arabia hopes to hinder the growth

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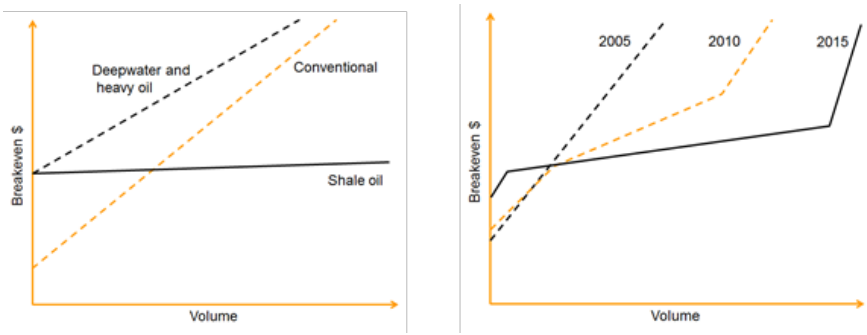
A lid on the oil price?

of US shale oil producers. The thing is, if or when this succeeds and US oil shale companies lower their output - and the price comes back up as a result of this – then there will again be incentive for US shale oil producers to relatively quickly return to the market. A conventional offshore well could take 5 to even 10 years to develop. The US shale oil producers can react in a few weeks. Some believe that US shale oil production has effectively put a lid on oil prices going forward.

A flatter production cost curve

With a larger mix of shale oil where production costs don't increase much with volume the production cost curve has flattened over the last few years as we have tried to picture below. This flattening will continue for as long as shale oil produces sufficient volumes. The players that Saudi Arabia will take down with the current price policy are rather the producers of deep-water offshore oil and of oil produced from oil sands that have much higher breakeven points. Complications in this game of chicken is that global oil demand has been weaker than expected and also that Iran is expected to increase their oil production after years of export sanctions has been lifted. Right now OPEC's production looks to increase in 2016 despite the oversupply. The OPEC meeting on 4 December will be interesting.

Picture 7.45. Production Cost at Different Volumes



Source: The author

Productivity up = breakeven down

ROP – Rate of penetration

NPT – Non-productive time

An interesting feature is that the average threshold price for shale oil producers is a moving target. In businesses that are more similar to a production process there is a larger potential for productivity increases from process improvements and technical innovation - especially in an industry as immature as drilling for shale oil. The breakeven price has potential to go lower due to process improvements in for example the time the takes to drill a well (increasing the so called ROP, rate of penetration – i.e. the speed at which a drill bit breaks the rock), the number of completions per well and reducing non-productive time (NPT). The shale oil producers have cut costs by 20 to 30 percent in a very short time as a response to the lower prices. To top things off enhanced production technologies like CO_2 flooding has yet to be applied to oil and gas production from shale deposits.

Anecdotal reports of pay cuts of up to 50 percent for some personnel have been mentioned in the press. According to ConocoPhillips CEO Ryan Lance the break-even shale oil costs has fallen by a third since the price collapse. The fact is that the heavy cost cuts among shale companies have put them in a

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Sorely needed

better relative position compared to other oil producers than prior the downturn. This is sorely needed as the US E&P sector has been a growth focused boom business with non-existent profitability, fueled by cheap debt. The average net debt-to-EBITDA is almost 3 times.

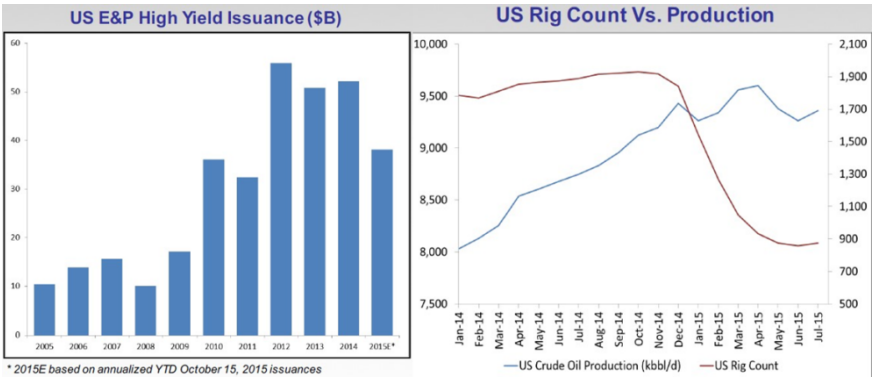
Production relatively intact – so far

A few of the weakest companies are also starting to collapse under their debt burden and a small number of bankruptcies have been announced. However, most bystanders probably would have foreseen a larger havoc by now. A leading indicator of the US oil production is the number of active drilling rigs. The rig count has displayed a dramatic fall since late 2014. Despite this the production is still more or less intact. Drilling has been focused to the most productive wells and the larger part of production volumes are actually supplied by companies with relatively better balance sheets and where only half of them are pure-play shale oil producers.

Credit availability surprisingly robust

Suppliers of credit also seems to look through the current trough in prices as they – probably correctly – foresee that shale production will have to grow in the future to satisfy oil demand. To further point to the ongoing productivity work in the US shale segment, during the upturn in volume 2012 to end 2014 the rig count was actually flat. The disappearance of marginal activity has not had any large effect so far and US oil production is actually expected to only show a single digit decline in 2016. The mid-term game is probably a consolidation wave that further could professionalize the US sector and improve the profitability.

Picture 7.46. US E&P High Yield Issuance and US Rig Count vs Production



A 45% drop in rig count has resulted in a 5% production decline – so far. Source: Kynikos Associates

Cash cost $ 30?

Over time the oil price should reflect the breakeven production cost of the marginal barrel that satisfies demand – or be slightly higher if OPEC can go back to withholding some of their low production cost volumes - and the flattening of the cost curve can have large consequences in this respect. However, in the short-run prices deviate hugely from this marginal cost pricing. For a company with a well already in production it is rational to continue to produce as long as the cash contribution is positive since the other costs have already been incurred and are sunk costs. This so called cash cost of the marginal producer has been estimated to about USD 30 per barrel by Goldman Sachs but estimates varies among firms.

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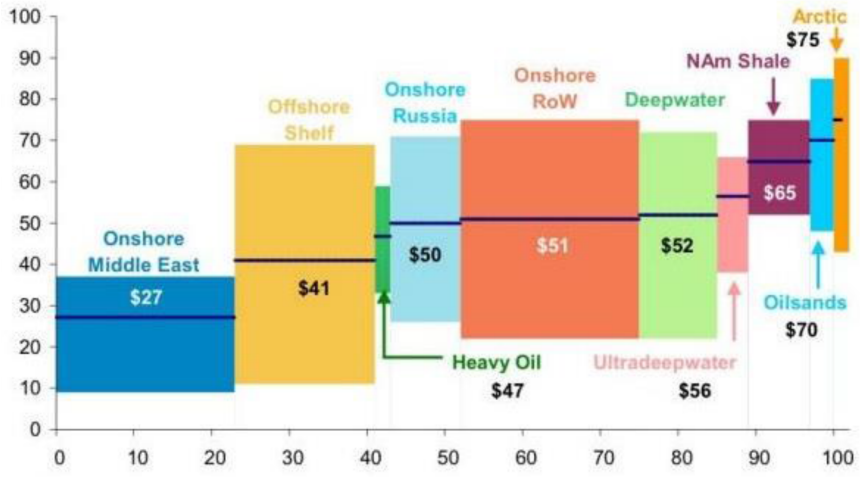
Picture 7.47. One Estimate of Breakeven Production Costs, $/bbl



Source: The Absolute Return Letter, January 2015, Absolut Return Partners, Morgan Stanley

Supply

Oil supply is a function of producers' capacity and will to produce crude oil from their proven reserves and of refineries capacity to process the oil into the required end-consumer products. Over time supply has been increased to keep pace with an estimated linear growth in demand.

Supply shocks

Now and then through history sudden negative supply side shocks have removed supply from the market and caused sharp price hikes. These negative shocks have been caused by geopolitical events like wars or OPEC deciding to lower their members' quotas. Positive supply side shocks were long seen as an event from the past before technological development released massive amounts of hydrocarbons from reservoirs in US shale rock causing the oil price to plummet. Admittedly this supply shock was not as swift as a sudden oil embargo but the effects have been far reaching nevertheless. Now there is a supply glut and supply volumes need to come down. When production volumes from US shale oil eventually come down prices can rebound as the spare capacity of OPEC right now is relatively low. This in turn can trigger renewed US supply growth.

OPECs raison d'être is to adjust supply to have an impact on the oil price. Thus, even though non-OPEC countries produce at full capacity, OPEC as a group and especially Saudi Arabia does not. Changes in OPEC spare production capacity is an important signal of how tight the market is. Those changes obviously come from the interplay of technical production capacity itself but also from changes in the demand for oil. If all OPEC countries in the long run can produce at will as today the motive to keep the cartel is gone.

How long can they take the pain?

The role of the OPEC countries isn't this straight forward however. They need a certain price level to balance their government budgets. With a continuously low oil price countries are faced with a decision to either cut government expenses and risk to enrage the population or make up for the low price by selling a larger volume – and by this risking lowering the oil price even more and create a vicious spiral. In the current situation even Saudi Arabia with a

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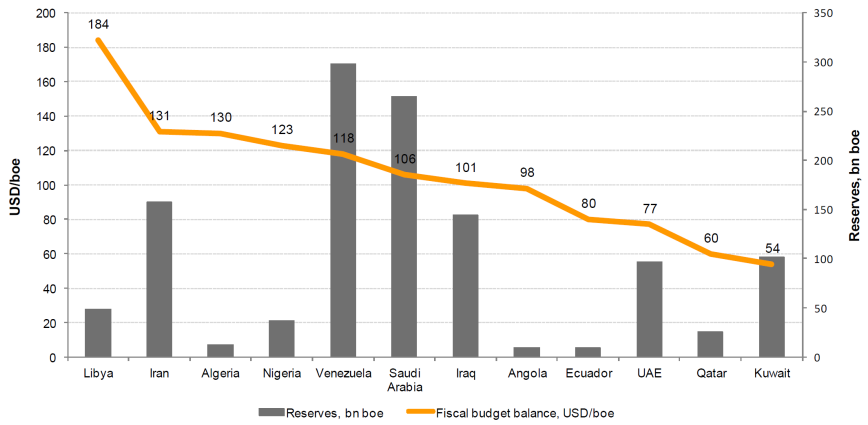
gigantic sovereign wealth fund has started to issue government bonds to finance its state budget during fighting a war in Yemen. Venezuela has started to sell off its government gold reserves.

Picture 7.48. Fiscal Breakeven Oil Price, Brent in $/bbl



Source: WSJ, OPEC (production); International Monetary Fund [break-even prices except as noted: Nigeria and Venezuela (Deutsche Bank); Angola (Angolan government); Ecuador (Finance Ministry)]. Numbers refer to 2015 break-even.

The role of the refineries mustn't be forgotten. When they run at full capacity refining capacity acts as a bottleneck for bringing products like gasoline to the end market. Refining capacity also affects price differentials between light sweet crude oils and heavy sour crude oils – the so called clean-dirty spread - as refineries specialize in one type of crude oil. With increased investments in refineries that can handle heavier crudes the clean-dirty spread has narrowed.

Demand

The demand for oil depends on the demand for its derivate products like gasoline, diesel and heating oil. Over time oil has been gradually replaced in industrial use and today the end demand is more consumer driven. The demand shows relatively low short term changes and low price elasticity as the services the products provide like transportation and heat is crucial for everyday life. The use of these products is however cyclical over the business cycle. In good times more trucks, boats and planes transport products. More people go on vacation and power plants at peak load have switches to running power plants on oil.

China

Going forward the growth in demand will to an overwhelming part come from Emerging Markets and not from the OECD area. To forecast future demand a fair grip of Chinese economics is a good thing to have. In addition to monitoring factors like OPEC spare capacity, oil and gasoline inventories etc. the Chinese import/export data could be key.

Spare capacity

Unexpected demand increases combined with low spare capacity will result in sharp price increases until new supply reaches the market. A lack of spare production capacity means producers cannot respond to price increases by increasing production, the price volatility often increases and buyers build in a

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security premium into the price as supply disruptions are much more likely. Tight spare production capacity can be mitigated by inventories of oil and changes in oil inventories send important price signals.

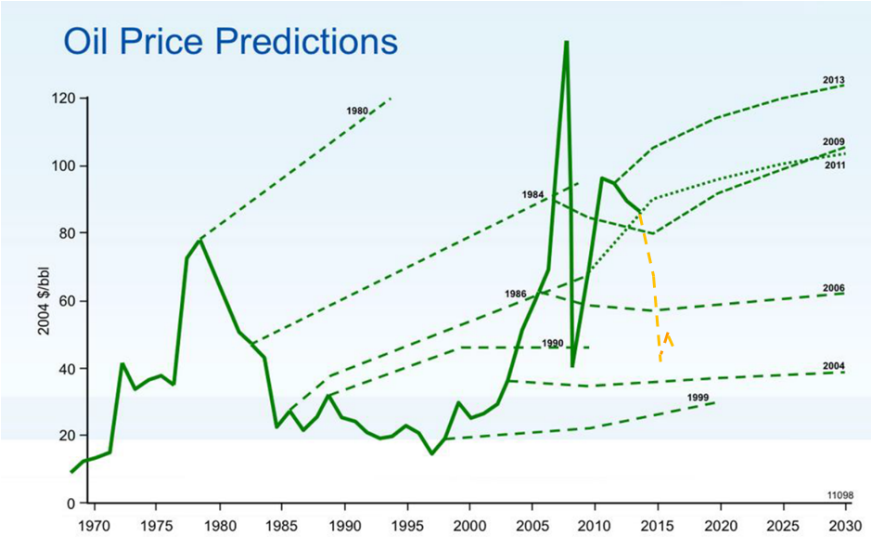
Predictions

The pricing of oil on the futures market and the estimates of others who forecast the future oil price very rarely are even close to being right. Demand is mainly governed by the GDP growth in various regions and forecasters' track record in pinpointing future economic growth is in itself rather poor to start with. Add to this a supply side that combines geological factors and technical development with political and environmental factors.

Too narrow and follow-on consequences are hard to foresee

Forecasters usually stick too closely to the current level of what they try to forecast and when change happen the effects are often underestimated. The full range of possible outcomes and the probabilities of tail end occurrences are seldom factored in into predictions. Further, even if the effects of changes are understood, second order consequences are hard to fathom (or third and fourth order consequences). The picture below that shows forecasts at various points in time in green dotted lines and the actual price development underscore the difficulty. Generally forecasters predict that the price in a not too distant future will be slightly higher than the present price, irrespectively of the starting level.

Picture 7.49. Forecasting…



Source: IEA and the author for the orange line drawn at free hand

Economic events are self-correcting

The price is set by supply and demand and we normally discuss the causality as moving from supply and demand to the price. However, the reverse is equally true. Oil prices at different levels will in turn affect the supplied volumes and the demanded volumes. With varying time lags economic events are self-correcting if market forces are allowed to play out. Dynamic effects are hard to forecast.

Even if exact price predictions are hard, an analysis of the forces at play and their interactions can give an opinion on the most likely direction of change in

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the near future. Prices are set by a combination of short term trends that often work to extrapolate the current momentum and by a long term reversal to the price that is motivated by the breakeven production cost of the marginal supplier.

Rising marginal production cost

Given the lack of predictability most oil companies base their forecasts exactly on the gradually rising production costs for the marginal barrel of oil that satisfies future demand volumes. Why is the marginal cost rising? Due to geography and other factors it is cheaper to lift oil from some reservoirs than from others. Naturally man has developed the more accessible reservoirs first and because of this there is a gradual increase in the production costs over time everything else alike. Over time oil exploration projects will be increasingly complex and capital intensive. According to Bloomberg the IOCs capitalized E&P costs have risen from 2.2 $/bbl in the year of 2000 to 9.6 $/bbl in 2014 – some of this is undoubtedly due to lax boom time processes however.

Long-term substitution

One difficulty in estimating the long-term balance between supply and demand for the various sources of energy is the substitution effects between them. The higher the price for one source of energy the larger the incentive to take investments that shift demand to other sources of energy, which in turn lowers the price for the first source of energy. In the short term substitution is low as the use of gasoline is quite separate from the use of other sources of energy and since equipment and machinery have been customized for one source of energy but over the long-term the interplay between various sources of energy is full of both self-enforcing and counteracting feedback loops. Prices are both signals and incentives.

For example high oil prices incentivise both switches to current alternatives such as gas usage in power plants plus innovations in new technology such as Elon Musk's efforts to displace gasoline and diesel as fuel for cars. The main fuel for cars would then be gas and coal as of now (but with renewables growing fast) and with a growing LNG trade, regionally high gas prices might see downward pressure as the gas market globalizes. Dynamic effects are hard to forecast.

Long-term energy demand

It has long been close to a natural law that secular demand levels for oil have risen over time and between 1983 and 2014 oil demand only declined once; in 2009 with 1 percent. Long term forecasts from organizations like OPEC and IEA still point to future growth. This should not be seen as an obvious thing to go on undisrupted though. Energy demand in OECD has been flat for a substantial period by now - mainly thanks to increased energy efficiency - and the energy content of the growth in Emerging Markets is declining fast. If the demand volumes would stagnate and stay flat at the same time as technological progress in oil production continues this could have severe long-term consequences for future oil prices.

Energy efficiency isn't as spectacular as many other factors in this industry but it yields more influence than many realize. The IEA long-term forecasts for energy demand have the last decade constantly been too high and have had

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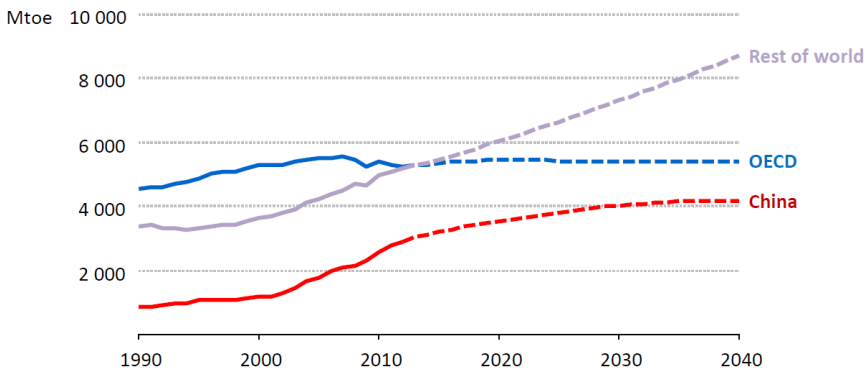
Energy efficiency

to be lowered time after another, simply because efficient use of energy is starting to be an everyday consideration in almost any setting. Today the growth forecasts from IEA have come down to quite reasonable levels and ironically they might even be too low since the decline in the oil price probably will incentivize a higher usage and demand. One scenario, not counting any cyclical developments, could be some years when Emerging Market growth trumps energy efficiency and the energy usage continues to rise. This is then followed by a period when the reverse is true until energy efficiency measures are depleted and the natural progression of higher energy usage continues.

Picture 7.50. Energy Demand by Region



Source: World Energy Outlook 2014, IEA

Depletion

The majority of the world's growing production of oil comes from fields discovered years ago and as an oil field has peak production relatively early in its life, production from these fields are declining. Some fields are new with increasing production but on average the above statement is true. Existing oil fields are estimated to decline ca 4.5 percent per year. This depletion means that a reserve volume equivalent of that of Iran has to be "found" yearly – or else the proven reserves of the world will shrink. The problem is that global oil discoveries of new wells peaked in 1965 and production has exceeded discoveries every year since 1984.

Higher recovery rate

Despite this seemingly impossible task to overcome, the volumes of proven reserves have grown the last decade. Why is that? The main reason is not shale oil or the new findings of other oil reservoirs. The main reason is the technical development in oil production in general that has meant that the recovery rate of oil reservoirs steadily has risen over time. The proven reserves are increasing because we are able to recover a larger percent of the oil in the reservoirs we are producing from. Technical progress has helped us to leave less oil in the ground. Old sealed wells are even being reopened to be worked on with new technology. If recovery rates for example increase from 40 percent to 60 percent over a number of years then this is a 50 percent increase of the total proven reserves. This is massive, it's a finite game and it will take increased costs, but it's still massive.

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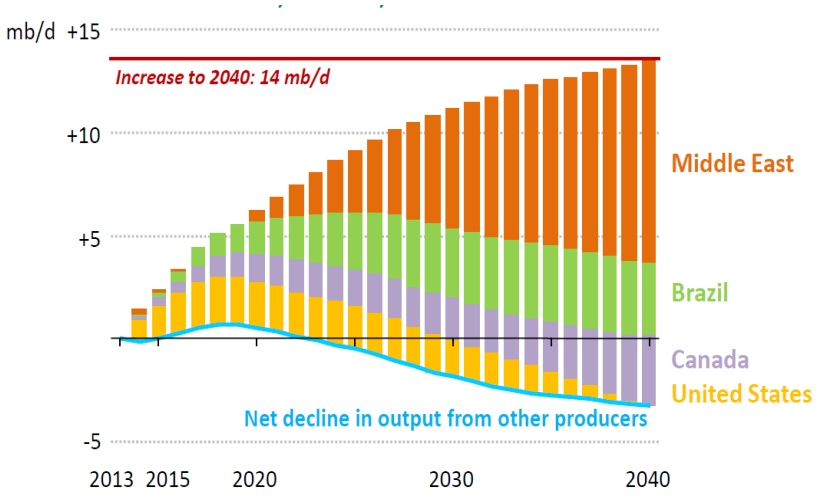
Picture 7.51. Oil Production Growth



Source: World Energy Outlook 2014, IEA

Peak oil…

During the 2004 to 2014 boom in oil prices the debate around the price often centered on the concept of peak oil. The theory argues that half of the world's oil resources have been recovered and because of this an imminent decline in oil production is nearing. Producing oil in a faster pace going forward will only empty the remanding resources faster. Not part of the theory itself, peak oil is often used as an argument for continued high oil prices, as supply will decline faster than demand. The 1950's belief in technological progress as revealed in L. S. Strauss prediction that "Our children will enjoy in their homes electrical energy too cheap to meter" had given way to dystopia.

…vs human ingenuity

The man behind peak oil was M. King Hubbert (1903 – 1989) who predicted that US oil production would peak somewhere in the years of 1965 and 1970. As US production hit a peak in 1970 Hubbert became an international celebrity, a prophet. He further predicted the world production would peak in the year of 2000. This prediction turned out to be wrong and later day peak oil-theorists now argue around possible future peak dates. Why didn't the second prediction work out? Mainly because of the same reason that US oil production in 2014 actually came back to the same volume that Hubbert predicted as the peak volume in 1970 – technological development, partly incentivized by the rising prices. What are economically recoverable resources is a constantly moving target affected by geology, economics and technology as well as the physical amounts of hydrocarbons.

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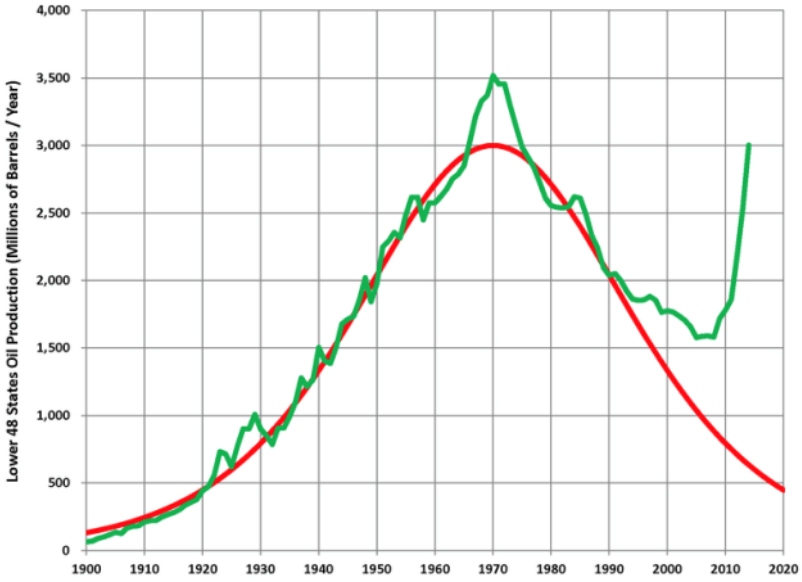
Picture 7.52. Hubbert's 1956 prediction of US oil production and actual production 1900 through 2014.



Source: Wikipedia

OOIP – Original oil in place

OIP – Oil in place

GIP – Gas in place

The concept of so called proven reserves is the amount of technically and economically recoverable oil or gas given today's technology and today's prices. The total discovered and undiscovered crude oil is called original oil in place (OOIP). Today's total remaining volumes of oil in place (OIP), of gas in place (GIP) and of other hydrocarbons are obviously finite but they are of vastly larger quantities than the proven reserves which is the number normally referred to during the debate.

Reserves

- Proven reserves (P1/P90) – 90% probability of recovery
- Probable reserves (P2/P50) – 50 to 89% probability of recovery
- Possible reserves (P3/P10) – 10 to 49% probability of recovery

Both SEC and the Society of Petroleum Engineers (SPE) issue - relatively similar - guidelines on reserve definitions. The amount of oil that is deemed to be recovered with a 90 percent probability under current economic and technical conditions is called "Proven reserves", or 1P alternatively P90. If the probability is thought to be between 50 and 89 percent the oil is called "Probable reserves" (2P or P50) and at 10 to 49 percent "Possible reserves" (3P or P10). Only 1P can be accounted for as an asset under US GAAP accounting. Most of hydrocarbons in place fall below even the 10 percent probability threshold as of today. Proven reserves are further sub-classified into Proven Developed Producing (PDP), Proven Developed Non-Producing (PDNP) and Proven Undeveloped (PUD) to signify the stage of development of the reserves.

Contingent resources

Discovered but yet uneconomical reserves are called not called reserves but instead "contingent resources". The contingency could for example be that the transport of the crude oil from a remote location hasn't been solved in a satisfactory way yet. Contingent resources are divided into a similar range as the reserves namely 1C, 2C and 3C.

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A moving target

As the classification of reserves uses estimated probabilities of recovery, reserves are a moving target. If the oil price goes up it becomes economical to develop a larger proportion of the oil in place increasing the proven reserves – and vice versa. If new technology lowers the cost of recovering oil it becomes economical or even technically possible to develop a larger proportion of the oil in place increasing the proven reserves. To add to the subjectivity of what is proven reserves at any given time is the fact that it's the producers themselves who estimate the probabilities and as the production quotas of OECD use the size of each country's reserve as the basis for their annual production and since no one really verifies the numbers there has existed a strong incentive to nudge the numbers higher.

80% of petroleum resources left – at least

The world is not physically running out of oil. According to the world-renowned energy expert Daniel Yergin the world has produced about 1 trillion barrels of oil equivalents since the start of the oil industry. Currently there are including unconventional sources at least 5 trillion barrels of petroleum resources left. We have more than 80 percent of the petroleum resources left! How large a proportion of these barrels that in the end will be developed will be decided by future technical developments and politics. The issue is not finite resources but the rate at which these very large resources can be converted into reserves for production.

Economic or political peak oil

At some future point the world will economically and politically run out of oil. As put by Saudi minister Ahmed Zaki Yamani "The stone age came to an end not for the lack of stones and the oil age will end, but not for a lack of oil". The oil age will end because humanity decides that it has preferred cheaper and more environmentally friendly options. Given that oil mainly is used for transportation further breakthroughs in car battery technology leading to longer mileage, shorter charging time and longer battery life span may be the main contender today to end the oil age.

Trying the impossible: an oil price prediction!

Our best guess is that oil prices stay sluggish until supply and demand balances and then moves to the now lowered price where the producer of the marginal barrel that meets global demand gets his production cost covered (~75$ bbl). After this there will be a number of years of price volatility around this gradually increasing marginal production cost (+/- 50 percent) and then in a decade or so demand for oil will start to fall off as the car fleet mix changes to electrical vehicles and the increasingly urbanized world population more often than not commute by buses driven by compressed natural gas (CNG) and other shared transportation means. But then again, we just showed you how much oil price predictions are worth…

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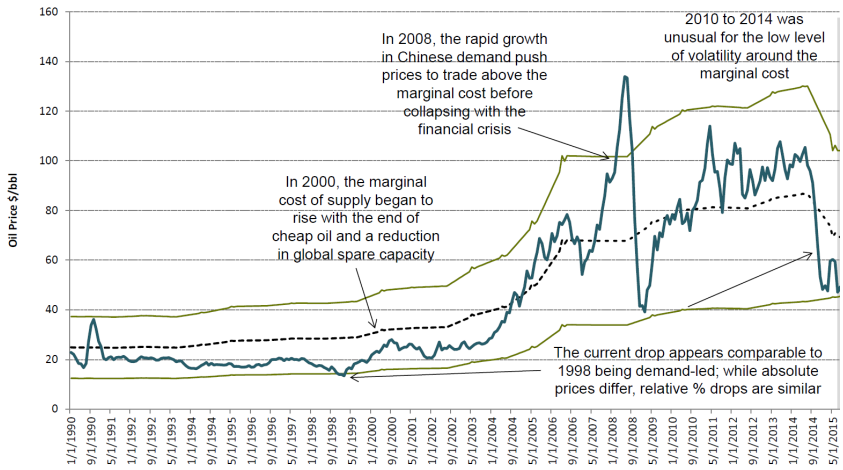
Picture 7.53. Marginal Break Even Cost



Source: Kimridge Energy, Echoes of '98, September 2015.

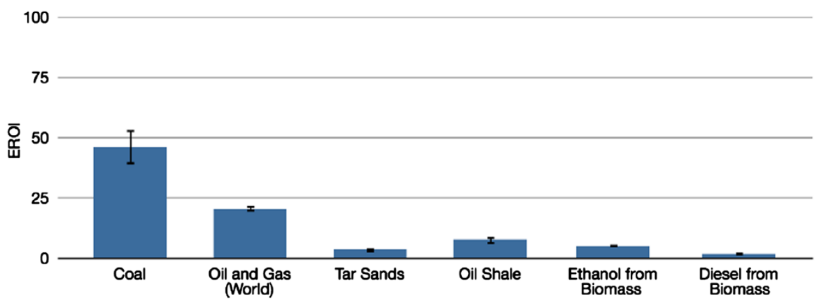
7.7 Gas, Coal and Unconventional

EROEI – Energy Return on Energy Invested

EROI – Energy Return on Investment

There is a wide array of current and potential sources of energy. How does one decide if a source of energy provides a worthwhile endeavor? The amount of energy from the produced resource divided by the amount of energy it takes to produce it with current technology is called energy return on energy invested (EROEI or just EROI). The closer to 1 that one gets the less profitable is the production everything else alike. The land based oil fields of the 1970s produced petroleum with an EROEI of 25. Conventional petroleum today is about at 15 to 20. Even if there are a large amount of unconventional hydrocarbons available the EROEI with today's technology might be too low. How and when future technological breakthroughs will improve the ratio is notoriously hard to predict. However, it's important to keep in mind that EROEI is a dynamic ratio.

Picture 7.54. EROI of Energy Sources



Source: Hall et. al. (2013).

The picture above shows the high EROEI of the conventional energy sources coal, oil and gas. Renewables have attractive ratios as well.

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Natural Gas

Natural gas is a combustible, colorless and odorless gas. Over the last 40 years natural gas has steadily increased its share of the global energy mix from 15 percent to 24 percent. In the US, the shale revolution has allegedly unlocked 100 years production of low cost natural shale gas plus vast quantities of shale oil. The global energy map has completely changed. And to top things off: US isn't even the largest holder of oil and gas reserves in shale rock. China has double the reserves of the US and Argentina, Algeria, Canada and Mexico have on average similar size reserves as the US. What has been different in the US case has been that there already was a vast natural gas pipeline network in place and with land rights in the hands of private owners the sector could develop quickly.

China largest holder of shale gas

Neither hydraulic fracturing nor horizontal drilling is specific to gas exploration but due to the large effects the technologies have had on the US shale gas revolution they are described here. Horizontal drilling is when someone first drills vertically to a required depth, then the drill bit is gradually turned horizontally using a downhole motor. Horizontal drilling is especially useful when the reservoir is not very thick but extends over a wide area. Hydraulic fracturing, or simply fracking, is a method to combat the low permeability of certain reservoir rocks, for example shale. By using fluids and high pressure to split the layers of rock, gas and oil are released from the pockets they are in and can be collected.

Horizontal drilling and hydraulic fracturing

Geologists have long known about the large shale gas and oil reserves that were locked up in the impermeable shale rock. However, it wasn't before the inflection point for the production technologies was reached that they became economically viable. Gas reserves previously dubbed "unconventional" are now expected by the EIA to make up almost 80 percent of natural gas production in 2035. The continued expansion of natural gas will in all probability have a further crowding out effect on "king coal" and especially if China starts to develop their shale gas resources.

Unconventional majority

There have been a number of worries about the development of shale gas mainly related to the risk of leakage of chemicals from the fracking fluids into the ground water, methane leakage into the air and fracking causing small earth quakes and other seismic activity. The former is relatively unlikely as the depth where the ground water resides and the shale reservoir rocks are, are massively separated. Leakage of chemicals into the groundwater can basically only happen if the casing of the well is broken. Leakage of methane into the air should also only happen if the equipment is faulty, say a valve doesn't close as it should or something similar. This is something that occasionally happens in all gas production but that is in the companies' own interest to avoid as the methane is what they sell. Stricter supervision might however be needed.

Worries

Not all focus could be on shale gas though. In the middle of the Persian Gulf is one of the most important marine demarcation lines dividing the area into Qatari waters and Iranian waters. Below the invisible line is the world's largest gas field and Iran has never been happy that Qatar is in position of the major

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The gas-condensate reservoir in the Persian gulf is called the North Field on the Qatar side and South Pars on the Iranian side

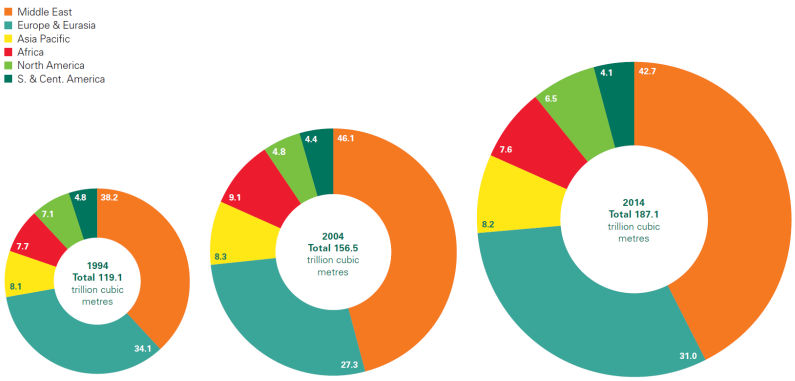
part of it as the border was negotiated before the field was known. With this field Qatar rivals Russia as the ruler of the natural gas world in terms of reserves. While Russia with its state owned gas giant Gazprom can reach prospective customers in Eurasia and Europe via pipelines and the US have a large domestic market also supplied by pipelines, Qatar has had to go with liquid natural gas.

Proven gas reserves

1. Russia
2. Qatar

Looking to global proven gas reserves the total volume has grown from 119 trillion cubic meters in 1994 to 187 trillion cubic meters in 2014. However, this doesn't tell the full story as to be counted as a proven reserve, someone would have to do the work to deliver geological and engineering data that show that a reserve is of economic value and should be recovered. Very little of the shale gas has been through such a process. The US market share of proven reserves grew from 4 percent in 1994 to 5 percent in 2014 – way behind Russia's 17 percent and Qatar's 13 percent.

Picture 7.55. Distribution of Proven Gas Reserves in 1994, 2004 and 2014, %



Source: BP Statistical Review of World Energy 2015

Gas production

1. US
2. Russia
3. Qatar

Probing into production the US shale revolution is more visible. With 21 percent of the production the US held the top spot ahead of Russia with 17 percent and Qatar with 5 percent. The US was the largest consumer as well with 23 percent of the global consumption. The only other country with a double digit market share of consumption was Russia with 12 percent. Qatar is the largest exporter of LNG with Japan as the largest LNG importer.

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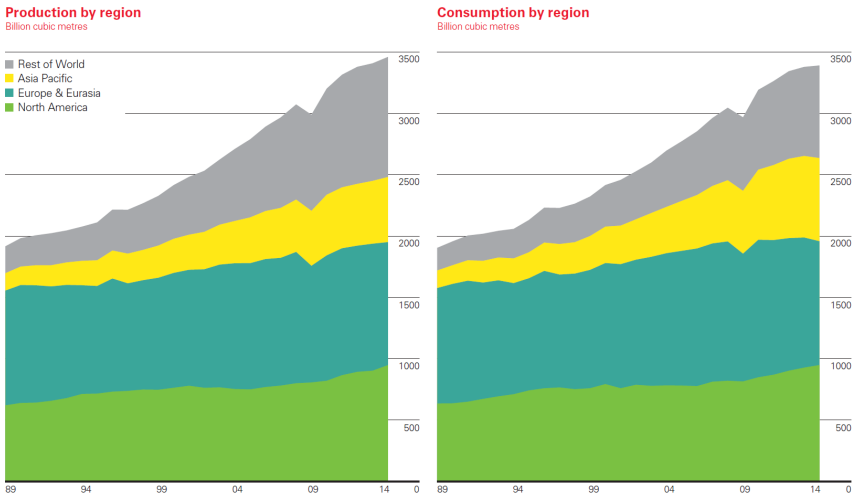
Picture 7.56. Production (left) and Consumption of Gas by Region (right)



Source: BP Statistical Review of World Energy 2015

75% recovery rate

Oil and gas are often found together even if different reservoirs contain different mixes of the two and are thereby dubbed an oil field or a natural gas field. Contrary to the relatively low recovery rates of crude oil natural gas wells generally give up 70 to 80 percent of their content with primary production techniques and sometimes up to 90 percent after secondary and tertiary recovery processing. Since oil is liquid it is easily transported. Pipelines predominantly must transport natural gas, meaning the market for it has been regional and not global. With the development of liquid natural gas this is changing as the gas becomes globally tradable and transportable – provided a price differential between regions that can cover the transport cost. As much gas over the years has been found at oil wells far from prospective customers it has simply been flared, i.e. burned at the well. Flaring is prohibited in many countries today since it wastes valuable energy and releases CO_2 to no use but it is still relatively widespread.

Flaring

Picture 7.57. Venezuela From Space At Night

Source: geology.com. Caracas has a population of 2.1 million. The Orinoco area is mostly jungle. Note that Venezuela should not be specifically vilified in this. Flaring is all too common.

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Seasonal demand

Spark spread

Still, gas has the lowest CO_2 emissions of all fossil fuels per unit of energy. The usage is divided between residential and industrial consumers and it has been gaining share of the global electricity generation at power plants. Residential gas is used for cooling, cooking and predominantly for heating. Thus, seasonality is a big demand factor with higher demand during cold winter months. Industry demand of gas goes to heating, melting and feedstock to the petrochemical industry. For power plants the expected spread between the price of the source of energy and the electricity price provides incentive to refurbish power plants to use varying sources of energy. The spread between gas prices and electricity, the so-called spark spread, has been high enough to make natural gas the perhaps most important energy source of new power plants globally.

Mcf – thousands of cubic feet

Btus – British thermal units

MMBtu – million British thermal units

BOE – barrels of oil equivalents

The quantity of natural gas is measured in cubic meters, in cubic feet or more often thousands of cubic feet (Mcf). The measure of the energy content of natural gas is Btu per standard cubic foot. One cubic foot of normal quality natural gas produces 1,028 British thermal units (Btus). Btu stands for British thermal unit and is the amount of heat that it takes to increase the temperature of a pound of water by 1 degree Fahrenheit. Natural gas is traded on exchanges in lots of million British thermal units (MMBtu). To facilitate the comparison with the energy content oil, companies also report gas volumes using the measure barrels of oil equivalent (BOE). 6,040 cubic feet of natural gas is equal in energy content to the average barrel of crude oil and is thus one BOE.

Still regional prices

Natural gas prices are driven by a combination of economic activity and weather since a proportion of the end use of the product is heating. The regional character of natural gas prices is visible from the price differentials in the picture below. The increase in supply from shale gas has depressed US prices the last 5 years (red line) and LNG port terminals in the US that were meant to function as import ports are converted to be export terminals. In Europe the prices have kept relatively stable (green and blue lines) while the stretched energy situation in Japan post the Fukushima Daiichi nuclear disaster has kept LNG demand and natural gas prices high. Asian spot prices have generally varied between European prices and oil parity.

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Picture 7.58. Gas Prices, USD/Mmbtu

Source: BP Statistical Review of World Energy 2015

Gas processing to make a commercial product to a large extent consists of separating different hydrocarbons and the non-hydrocarbons in the gas and by this creating so called dry gas. Oil, condensate and NGLs are separated from the gas. As mentioned before, hydrogen sulphide is especially important to remove as it has a foul odour, it's corrosive and above all it is poisonous and lethal even in small amounts. However, most of the non-hydrocarbons are plain water vapour and it is separated either by condensation or by chemical agents. Since the gas is transported via pipeline it is often convenient to process the gas close to the well to not risk corrosion.

Henry hub

Henry Hub is the pricing point for natural gas futures traded on NYMEX. It is a pipeline hub in Erath, Louisiana and derivate prices are set based on delivery to this geographic location. Western Europe has no single Henry Hub equivalent. Local gas prices have historically been correlated to oil prices. Over the years the usages have shifted so that oil today mainly is used for transportation through gasoline and diesel and gas is mainly used for electricity and heating. Switching usage between the two is increasingly difficult and requires major capital investments and thus the prices are no longer joined-by-the-hip.

In 2008-10 there were brief discussions to create an "OPEC for gas" as the main gas producers Russia, Iran and Qatar tried to influence gas prices. With the emergence of the US as the largest global gas producer this venture has probably been put on ice.

Liquefaction – producing a liquid from either a solid or a gas

So what is liquid natural gas (LNG)? Natural gas of high methane content can be liquefied to a colorless, odorless, nontoxic and noncorrosive transportable liquid. The LNG plant, that costs between USD 5 to 10 billion to construct, consists of one or more so called LNG trains that cool the gas to -163 °C. The step is called liquefaction (Liquefaction – a process which produces a liquid from either a solid or a gas). As a liquid it only takes up 1/600th of its original space. This means that it can be readily transported on a ship. The LNG is loaded to purpose-built LNG ships that keep the gas chilled during the voyage

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to a regasification unit. Here the gas takes on its original shape and can be transported to end customers through pipelines.

LNG ships often have spherical tanks making the boats look like they carry a series of balls. With today's low gas prices the capital intensity and the energy costs of liquefaction and transportation costs threaten to make LNG uneconomical. Regasification is in contrast relatively simple. A receiving terminal consists of a berth for the LNG tanker plus vaporizers and storage tanks for further transportation. Regasification can also be done on certain vessels.

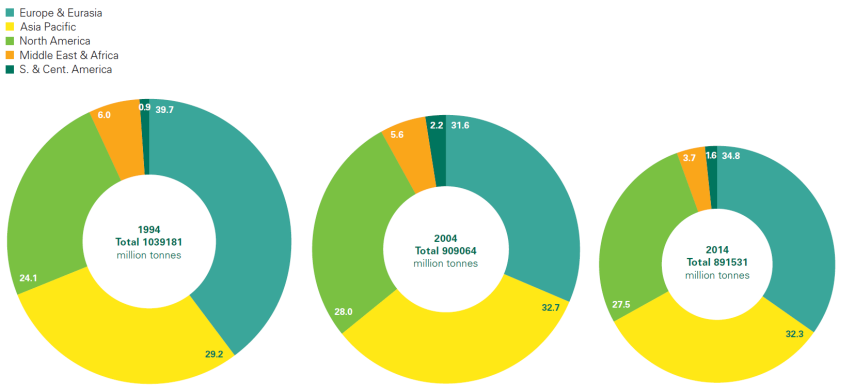
The cost of freezing the gas, transporting it and reheating it is high while the gas prices are volatile. Historically, this has meant that LNG has been sold on long contracts at fixed prices. By discarding this model and selling on short-term contracts Qatar has emerged as the world's number one supplier of LNG. Driven by price differentials between different regions and by cheap credit, the last few years have seen a boom in building LNG projects in Asia, Australia and Africa. Early 2015 there were 373 LNG carriers in use around the world, up from 143 in 2004.

Coal

Not in short supply

Coal is mainly used for power generation and is not considered to be in short supply. Because of this it is cheaper than most other energy sources. Coal firms own and operate coal mines, selling their output to utilities companies. Much like natural gas it is rather a regional business than a global one. It is further a cyclical commodity business with high capital intensity and large swings in profitability mainly due to changes in coal prices but also transportation costs and environmental policies.

Picture 7.59. Distribution of Proven Coal Reserves in 1994, 2004 and 2014, %



Source: BP Statistical Review of World Energy 2015

Mined

Seams of coal are buried underground. In the less expensive surface mining coal is extracted from deposits less than 60 meters underground. In underground mining the coal is produced from depths below the same threshold. For the last decade coal has had the largest volume growth of all sources of energy driven by the furious pace of Chinese economic

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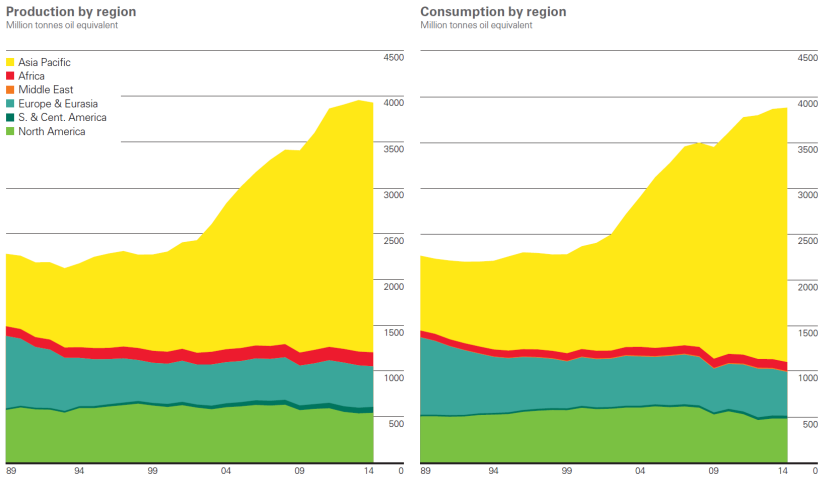
development. In 2014 this growth grinded to a halt when China's usage slowed and the transition to a more consumer lead economic model started to become visible.

Picture 7.60. Production (left) and Consumption of Coal by Region (right)



Source: BP Statistical Review of World Energy 2015

Thermal coal and cooking coal

Coal is divided into two basic types with regards to usage: thermal coal that is used for electricity and metallurgical or coking coal which is used for making steel. Thermal coal is ground to a powder and fed into a boiler to produce the heat that creates the steam to drive the turbines and generate electricity. Carbon steel is an alloy combining iron and a proportion of metallurgical coal.

Brown coal and black coal

Apart from producing the highest amount of CO_2 per amount of energy, burning coal also emits sulfur, nitrogen oxide and mercury. The expression brown coal (or more formally lignite) is the lowest quality coal with the lowest carbon content and the highest oxygen, hydrogen, sulfur and water content. At times black coal is used as a name for the other harder higher grades of coal (Subbituminous, Bituminous and Anthracite coal). Brown coal is the worst pollutant of the two and the texture is more like compressed soil than rock.

Clean coal

So called, clean coal technologies are a number of technologies developed to mitigate the environmental impacts of coal usage. They include washing impurities from the coal, treatment of polluting fuel gases, carbon capture and storage and dewatering of brown coals to improve the efficiency of its power generation. Further, coal gasification is a technology combining coal, water and oxygen to produce a gas mix of methane, carbon monoxide, hydrogen, CO_2 and water. After separation of the components the coal gas can be used for power generation and 99 percent of the pollutants will have been removed. The downside is the cost of the process.

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Unconventional Hydrocarbon Sources

Unconventional hydrocarbons are the ones that are produced using less usual and often more expensive methods. What is dubbed unconventional has evolved over time as economic and technical conditions change.

Oil sands

Oil sands (or tar sands) are reservoirs of very heavy oil, or bitumen, of high viscosity contained in sand instead of within pores inside a rock. The bitumen contains a large amount of asphaltene molecules and oil produced from oil sands have a °API of about 10 and is classified as extra-heavy. Most of the oil production from oil sands comes from Canada and Venezuela. The bitumen is generally situated close to the surface where lighter hydrocarbons have had the chance to migrate to the surface leaving the heavier hydrocarbons behind. The extraction is often from an open pit and more resembles mining for oil than drilling for oil. The location of the oil sand is generally well known. The economics of oil sand extraction is thus one of lower fixed costs and upfront investments but relatively high variable costs for staffing and treatment of the oil sand. It is more of an industrial process than exploration.

Hydraulic and electrically powered shovels scoop up the oil sand. The surface mined sands are then transported with trucks, draglines, conveyor belts or pipelines to a separation facility where the sand is treated with hot water and caustic soda to create slurry. Finally, centrifuges are used to separate the oil from the sand. The heating uses large amounts of natural gas that adds to the cost of production. The produced extra heavy crude is sold to a discount to lighter crudes and is either mixed with lighter crudes or sent to a refinery to be cracked into synthetic crude oil.

3.5 trillion BOEs!

The total reserves of oil in oil sands are estimated to a stupendous 3.5 to 3.7 trillion barrels oil equivalents. The problem is that with today's technology the EROEI is less than 2. How much of the oil sands that will be economically viable to extract is a question of technical innovation, future oil prices and political concerns – oil sands release about 40 percent more CO_2 than regular oil if all processing is included and the extractions leave ugly marks in nature. Open pit extraction leaves very visible scars in the environment compared to drilling for oil and has thus been heavily criticized by environmental pressure groups.

Canadian oil sands in the Alberta region have been a part of the North American energy revolution the last few years and vast investments have been pooled to this sector. With rising volumes the breakeven cost has come down. It is still higher than many other sources of oil and production might in the near term be halted. Just as with shale oil and gas the productivity in the production of crude oil from oil sands will however increase over time.

Oil shale

Oil shale is not to be confused with shale oil (which is sometimes also called tight oil and is the oil recovered with shale gas). Oil shale is rock that contains solid bits of kerogen; a precursor to oil that hasn't been exposed to the sufficient amount of pressure and heat to produce oil or gas. This can be fixed. By breaking the long hydrocarbon chains of this pre-oil rock with heat in the

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presence of additional hydrogen gas lighter hydrocarbon molecules can be created. Oil shale has been found all around the world and is estimated to between 1.8 and 2.8 trillion barrels of oil equivalents but the costs of mining, transporting, crushing, heating, hydrogen mixing and of the disposal of waste makes the extraction uneconomical at today's technology and oil prices.

Deep gas

Unconventional natural gas is a very large proportion of the total gas in place and is expected to represent a growing source of fuel in the future. Shale gas is of course a part of this. Deep gas is typically gas situated below a depth of 15,000 feet, which is much deeper than traditional gas deposits. Even if drilling and exploration improves, drilling deep is expensive and lifting costs are higher. Future demand will determine the economics of exploration.

Methane hydrate

Beneath impermeable solid sediment on the ocean floor and beneath arctic permafrost the substance methane hydrate is trapped. Methane hydrate is methane molecules caged in a lattice of ice and it looks like melting snow. If methane hydrate is warmed or depressurized it will revert to its two components water and natural gas. When brought to the Earth's surface one cubic meter of gas hydrate releases 164 cubic meters of natural gas. Although still speculative, methane hydrate seems to be much more prevalent than first thought. The US Geologic Service estimates that the amount of methane hydrates may contain more organic carbon than the world's coal, oil and conventional natural gas combined. This has yet to be sufficiently substantiated.

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7.8 Energy Investing

The oil price

USD exchange rate

If you could only know the oil price one year ahead of time investing in oil companies would be dead simple as share prices pretty much follow the spot price up and down. Even those companies that don't live from selling crude oil generally live from performing services or equipment to those who do. Equally if you could know the USD exchange rates in advance it could work as an indirect and imperfect way to estimate the future oil prices.

In this section we will first dive a little deeper into the economics of the companies in the sector and then discuss ways to look at the companies as investments.

Cyclical and average profitability

The oil industry is highly cyclical. It is very profitable over stretches of years but on average over time the return on invested capital is not higher than any other industry. The high profitability of the 1960's is long gone. In fact the return on capital has on average not been higher than the cost of capital and the sub-sector with the highest historical averages is the mundane oil & gas equipment providers – refineries have had the lowest returns.

Integrated Oil Companies

Location, location, location

Profitability in upstream activities is not surprising a function of commodity prices, production volumes and costs. Oil and gas are commodities and prices are set on global or regional commodities exchanges. Thus companies are price takers. In a commodity business it is the low cost producer that reaps the majority of the long-term profits. A traditional oil company's cost position is mainly driven by the geography it operates and the size of the government take, but also by the transport cost it has to bear to transport its product to the customers. The pure lifting cost that is the part the company can control itself is a relatively small part.

At times even the part of costs that the companies can control themselves become paramount and cost consciousness among oil companies goes in cycles. When the oil price is high, attention to boring frugality is less and when the price declines cost cutting climb to the top of management agendas. The total finding and lifting costs per barrel decreased for two decades up until about the year of 2000 but have risen steadily after that. A trend that is destined to reverse again.

Rising capex and opex

For long the oil price per barrel was USD 10 to 20 and the industry generated a ROCE of 13 percent. Then over two decades the price went to USD 110 and the industry still generated a ROCE of 13 percent. During 2004 to 2007 ROCE was higher but that was mainly as the industry had underinvested earlier in the decade. Over the last decade opex/bbl but especially capex/bbl have seen a rapid increase. Swedbank forecast an oil price of USD 65 next year and USD 75 in 2017. Hence, the agenda has distinctly moved to cost cutting and stocks that surprise on the upside in this discipline can be good investments. Belts are being tightened.

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Complexity and complacency

Some of the cost inflation is unavoidable with increasingly complex projects and offshore production at increasing depths. Other parts are at least partly due to the windfall of previously high oil prices and a lost focus on operational excellence. Wages in the sector have risen way faster than inflation, drilling productivity has gone down, bureaucracies and gold plating of designs (for example of topsides) have been building up and project delivery time and cost overruns are more common than they should be.

Best practice and replication

Going forward, lower costs will be realized from a number of sources. IOCs will obviously start with renegotiating their contracts with suppliers, processes will have to be re-engineered and simplified, the amount of local content will probably come down, salary cuts are difficult to pull off in some areas but easier in others and the industry must focus a lot more on best practice and replication. Too much of equipment is unique and purpose built as of today.

Local content

An increasing number of governmental lease agreements have the last few decades included local content policies (i.e. the use of local staff and the purchase of locally produced components) to promote the development the domestic industries of countries. This has substantially increased the cost of projects. For example Technip has stated that subsea components produced in West Africa can be 4 times as expensive as imported ones. Potentially, IOCs leverage to negotiate contracts with less local content will increase going forward with the pressure the low oil price puts on governments. Geology creates an underlying upwards cost pressure but the next few years can see a reset of breakeven costs thanks to increased efficiencies before the price starts to increase again.

Oil companies plan and budget for a certain percentage of E&P costs that cover a portfolio of projects. This is like the R&D-budget for a Pharma company. It has to be spent to generate future business but the money still has to be spent as efficient as possible. As with R&D there is no correct percent of sales but the goal is often to spend enough so that the proven reserves don't shrink.

Selling their assets

Companies in most other industries use the assets on the balance sheet in the manufacturing of something that is later sold. The assets for an oil company are different. They mainly consist of oil reserves and it is the assets themselves that are sold. This means replacing those assets is vital or else the source of something to sell in the future is disappearing. Reserves can be replenished by a company finding new resources, improving the recovery ratio or by buying assets from other companies or even buying asset rich companies.

Reserve accounting

IFRS does not give any detailed guidance on how reserves should be accounted for. Therefore oil companies generally look to SEC guidelines or to Society of Petroleum Engineer's guidelines on when reserves can be recognized and the prices they can use when valuing the reserves. As mentioned before companies are only allowed to book proven reserves as assets on the balance sheet.

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Cost accounting

Companies have 2 options in accounting for pre-production costs including the license costs. With the full-cost approach they capitalize all E&P-costs including those of dry holes. With the successful-efforts approach only the E&P-costs associated with wells that produced proven reserves are capitalized and the rest are expensed. When the well starts its production the capitalized E&P costs are transferred to PP&E and depreciated yearly with a sum that represents the year's production as a percent of total estimated proven reserves. Direct lifting costs are naturally expensed as they occur. Costs associated to a project don't end with the end of production. Lease contracts stipulate that fields are returned to their pre-production state. Decommissioning costs must be recognized upfront in the accounting and the companies make provisions for the future event.

Barriers to entry

Which competitive advantages and barriers to entry exist in the industry? For any company engaged in E&P the overwhelming source of competitive advantage is derived from a low-cost resource base. The ability to produce crude oil at a cost below the price set by the production cost of the marginal producer is in a commodity market the main way to generate a ROIC below the WACC. Geology is the most important determinant of production cost. Larger reservoirs, closer to the surface – preferably onshore, with reservoir rocks that give better opportunities for a high recovery rate and situated in low political risk countries with low government take in a close proximity to buyers would give a producer an edge over competitors. The problem for IOCs is that to gain this edge they in many countries have to pay dearly for it in competitive auctions and most ends up as government take.

There are scale benefits as in all capital-intensive industries but since so much of the work is outsourced and because so many fields are joint ventures they are not as large as might be imagined. Scale however gives a diversification effect lowering the impact from unsuccessful exploration or even from a disaster as BP's Macando blowout. Further, with increasing scale comes the ability to participate in the very largest projects. Potentially the oil price declines have also temporarily tipped the balance in favor of the IOCs in relation to NOCs. With lower oil prices the more efficient operations of IOCs compared to those of NOCs in general makes them more attractive for governments to use.

Finding skills

Although not a huge cost item for an IOC, the ability to cheaply and successfully find and develop oil and gas do offer differentiation between companies. Some companies have teams with long stretches of higher than average hit ratios in generating oil from wildcat drilling.

Other Oil Companies

The exceptions to the oil price dependence are refineries that have crude oil as feedstock and those firms who transport oil like oil tanker companies or pipeline operators. Low prices due to a supply glut could even mean larger transportation volumes of crude oil.

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Refiners

For refineries refinery margins, the so-called crack spread, is paramount but due to the capital intensive nature of the business capacity utilization is an important runner-up. A refiner is caught between two market prices: the price of raw material he needs for production and the finished products he intends to sell. If prices on both markets move in beneficial directions profits will be plentiful. If both move in adverse directions losses will be plentiful. The crack spread is a concept used to estimate the price differential between a mix of typical output products and that of the input price of crude oil. The most common crack spread relates the price for 3 barrels of crude oil to 2 barrels of gasoline and 1 barrel of distillate fuel oil, the so called 3:2:1 crack spread. If the price of the combined barrels of gasoline and distillate fuel oil is higher than the price of the three barrels of crude oil feedstock than the crack spread is positive.

3:2:1 crack spread

Hence, refiners benefit from rising gasoline and diesel demand, falling gasoline and diesel inventories, falling crude oil and natural gas prices, rising crude oil and natural gas inventories and of course rising capacity utilization.

Refiners can gain access to feedstock at a lower price than competitors by being able to buy lower priced heavy sour crude. The competitive advantage that comes from this cost advantage is however limited as the ability has to be preceded by capital investments. To some extent a close proximity to oil and gas wells can give some cost advantage. The risk is that this advantage comes with an increased distance to end customers.

Value chain integration

In contrast to independent refiners the refineries owned by IOCs have a natural hedge as they control the entire value chain and the IOC will only be dependent on production costs and the pricing of end-products, not on the prices of crude oil or of gas. However, this argument only holds fully if the production capacity and the refining capacity match 100 percent in both volume and mix between light/sweet and heavy/sour crude oil. The upside of the independent refiner is instead the increased flexibility to respond to price changes in various feedstocks.

Oil equipment and service

Oil Equipment and Service companies are subject to the variations in capex and opex spending for the larger IOCs and NOCs. In times of low oil prices and strained finances E&P-projects are pushed forward and with this the revenues disappear under the subcontractors feet and dayrates plummet. In good times there is a shortage of rigs, staff and equipment and the reverse demand and pricing conditions are true. For firms with a higher proportion of long-term fixed contracts in for example oil production the variability is lower. As in many industries it is often profitable to “sell the spades to the gold-diggers”. A number of oil service firms have generated good ROCE over time.

Drilling rig suppliers

Drilling rig suppliers seldom have any sustainable competitive advantages. Customers often tender jobs and let several competitors bid on business. Quality, availability, safety track record etc. are hygiene factors and price is often what decides who will win the tender. Temporary advantages can be gained from a strong balance sheet in troubled times and a large number of rigs improve efficiency as specialized staff can be deployed over more projects

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cutting idle time. The business is capital intensive and small players can be at a disadvantage. But in a world where the price of money is close to zero, capital is not really such a strong barrier to entry and in good times too many rigs are built by the many larger players causing overcapacity in downturns. Large investments might act as a barrier to entry for smaller competitors but when investments eventually are done they act as a barrier to exit. It's hard to find alternative use for a drill rig - or a refinery for that matter.

Pipeline operators

Pipeline operations are similar to refineries in that they are capital intensive and in addition to utilization of the pipelines companies try to maximize the throughput of the hydrocarbons. Generally storage and transportation companies are not affected by the swings in commodity prices as they have fee based business models. They provide a service and get paid in accordance to the handled volume. Still, some US based MLPs have run into financial issues lately. The problem has been that GPs were entitled to a special bonus on distributions to LPs above a certain threshold. By this GPs had incentives to increase leverage and distribute as much in dividends as possible at the expense of longer-term investments. The toll booth model is in principle a low risk business but in the case of an overcapacity of pipelines and declining US oil and gas production it could still be painful.

Investment Strategy

Long term

- Low cost producer
- High ROCE services
- Cheap on dividends

Depending on an investor's time horizon the investment strategy in the sector will have to vary. The long-term investor should focus on the low cost producers and the equipment and services companies that post the highest through-the-cycle ROCE as long as they are not too expensive. When measuring the valuation level dividend based metrics have proven to be effective for the larger companies.

Mid term

- Think in cycles
- Keep it simple
- Patience!

With a mid-term horizon an investor should try to exploit the cyclicality of the industry. Most of the industry, but perhaps especially oil tankers, oil rigs and to some extent pipelines go through cycles of over and under investments. Capex increases when customer demand, cash flow and availability to credits are strong causing overcapacity, falling prices and plummeting ROCE when demand falls away. During periods of low demand, weak cash flow and tight credit availability there will be little if any investments leading to undercapacity, rising prices and soaring ROCE when demand comes back. An investor should buy in times of overbuilt capacity after the oil prices has dropped, the demand has fallen away, dayrates have declined and weaker companies are fighting default.

Buy stocks in the relative safe companies that can withstand prolonged bad times and hold them until a few years later the reverse market conditions are at hand and retail investors march into the companies through ETFs. To succeed it is vital to always remember to think in cycles, to keep it simple and buy good enough companies when risk reward is skewed to the upside and to have the patience and resources to wait for the fortune of the industry to turn.

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Short term

- Predict oil price
- Time the relative movements sub-segments
- Company specifics

The shorter-term investor will generally have to play the expected near term oil price changes as different sub-industries react very differently to the price changes. Naturally, there are a number of short-term company specific events that will make specific stocks winners or losers and we urge you to listen to the excellent advice of Swedbank's analysts in this regard. Many small and mid-sized companies unfortunately have almost constant funding challenges. When the oil price bails them out or when funding solutions are found they can rally hard but over time it is not a profitable segment to be continuously exposed to.

Reserve life or the R/P ratio or reserve replacement ratio all aim at same thing

The amount of proven reserves is key in how investors are judging oil companies. Investors look to a company's ability to replace proven reserves with new oil. Declining reserves equals diminishing future revenues. Reserve life is a measure of the number of years a company can sustain its current production pace with current proven reserves. Stocks in companies with declining reserve life are seldom good investments. The reserve life is sometimes called the R/P-ratio. The parallel measure, the reserve replacement ratio is calculated as follows:

RRR = Movements in reserves (discoveries and extensions + revisions & reclassifications + improved recovery + acquisitions – disposals) / Total production for the year

Bottom up vs going concern

When valuing small and mid-sized oil companies that hold oil and gas resources analysts often model them bottom up on an asset-by-asset basis. The value is built up from the firms producing reserves and potentially from an allowance for upside in future exploration. One important thing is then calculating the government take correctly at different volumes. Large IOCs have too many assets and they are not disclosed well enough to be valued this asset-by-asset way. Instead, they are often valued as a going concern by looking to levels of growth, replenishment of reserves, return on capital and dividends.

Headwind IOCs

Some NOCs are listed but otherwise the traditional investment alternative in the energy industry group has been the IOCs, i.e. the large integrated oil companies. Everything has a price but the IOCs have a lot of factors stacked up against them. They face the burden to combat the decline rate in their reserves and this is all the more difficult as the IOCs actually have very small exposure to shale reservoirs. Producing oil from deep offshore wells and from wells in remote areas like the Arctic will require higher levels of capex-to-sales and higher costs over time. Furthermore, the NOCs have the definite upper hand with regards to access to future oil reserves and to top things off the IOCs are the prime targets of environmental regulations.

A virtual IOC?

An alternative to investing in IOCs is to build a portfolio of several holdings of independent companies and build one's own virtual integrated players. In this the investor gains flexibility and entrepreneurial spirit but trades away scale benefits and lower transaction costs. This is a higher risk/reward alternative in the short run but not necessarily in the long run.

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Indicators

The main share price drivers are the commodity prices such as crude oil and natural gas and for companies involved in E&P when major reservoir discoveries are made. Investors further look to a number of indicators including decline rates (that vary widely between companies). Share price developments have often been correlated to companies' upstream production growth – organic or not. The amount of capex per barrel gives a measure of the capital intensity of companies. ROCE is often looked to as a quality measure. Over time the companies with the highest ROCE will survive and gain share on the expense of competitors. However, the largest share price delta at any given moment will come in companies with lower ROCE and higher leverage. To invest with the latter low quality group requires market timing abilities that are hard to come by.

Valuation ratios

Some of the most commonly used valuation multiples are EV/DACF (debt adjusted cash flow) and PE-ratios which both look to the profitability of the company plus P/NAV and EV/bbl of reserves that look to the assets of the company. The former measures have tended to work better for oil services companies and investors look to all of them when analyzing IOCs. However, more than anything else IOC's shares trade on their expected future dividends.

Dividends

A dividend discount model forecasting the next few years' dividends has proven to be a good model to generate a predictive absolute valuation of IOCs shares. For an investor it is then critical to understand how well the company's cash flow will cover dividends going forward. In times when oil prices go down, the operating cash flow of the companies plummets and as necessary capex still has to be spent there is often a risk that dividends will be cut and by this further hurting the share price. The alternative is of course to cut capex to keep the dividends which is something we see all over the industry right now. The problem is that lower capex and especially lower E&P expenses will lower future revenues and the future ability to pay dividends.

Timing vs positioning

It might be hard to forecast the timing of short term market changes, but it could be possible to prepare and position the portfolio for them. Look for scarcity and bottlenecks and create scenarios for how the situation could change, try to be ahead of the curve and react to the first signs of this happening.

Happy investing.

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