POLITECNICO DI TORINO

Department of ENVIRONMENT , LAND AND INFRASTRUCTURE

Master of science in petroleum engineering

PETROLEUM DRILLING PATENTS ANALYSIS

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JULY 2019

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Chapter 1

Oil and gas industry , impact and future developments :

1.1Introduction

Petroleum is a liquid or gas that is found in rock formations under the ground. It is mostly compromise of organic compounds and some impurities. There were two ideas about the formation of petroleum, which will divide into two group organic and inorganic theory. Gradually, by doing experiments scientists were able to put aside the inorganic theory and they reached an agreement to deem that oil is formed by remaining of organic material who went through three stages in the terms of oil geology. After the accumulation of remaining, they should go through geological conditions in terms of pressure and temperature and gradually they will turn into petroleum. Furthermore, what distinguish oil from gas is their difference in terms of composition as well as their forming condition. oil is mostly compromise of heavier components mostly from c7+, however gas is mostly consist of lighter components c1 to c4.

Oil is not only specified to early history and there are some evidences that shows that it has been used by making for over 5000 years. Meanwhile, there are links which related history of petroleum to fire ablaze. Throughout human history, energy has a great major effect on improving the living standards. Mankind is depending on it in order to survive and make their necessities. However, it is not only specified to energy making and it can also be used as building material Before oil, wood was consumed mostly by mankind all over the planet.

In 18 the century, due to the industrial revolution mankind was thriving for energy and the amount of wood that they had was not sufficient in order to provide their necessities in terms of energy. As a result, they had to look for replacement which lead to coal. Coal was a great replacement and mining industry found a great of coal in order to provide the require energy for industries. A half ton of coal produced four times as much energy as the same amount of wood and was cheaper to produce than wood. Due to the environmental concerns and new technologies. Mankind was forced to shift to oil which was cleaner compare to coal and wood.

However, the discovery of oil is way back into human history and mankind was not able to understand the power of this material so far. The first oil was discovered by Chinese in 600 B.C and it was transported in pipelines made from bamboo which is widespread throughout their country. However, in 1859 oil was discovered in Pennsylvania and in 1901 in Texas which set the stage of new oil economy. Mankind was amazed by this black material and the amount of energy it can produce. Soon they put their effort to make new discovery methods and improved drilling methods, which were more sufficient (petroleum geology introduction , Dr. Mohammad Rezaie, 2015) .

Although, some believe that American were pioneer in petroleum industry on the other side of the world in the country of Russia, they drilled their first well way sooner than any country. The first well in Russia were drilled in the 9^{th} century and were also used to produce a solution of common salt which was also their necessities. The development of oil production began with advancing in technology as I mentioned. Oil was extracted in small amount until the mid19^{th} century. Due to the technological limitations at that time, engineers were able to drill shallow wells and do not possess suitable tools to drill deep holes. Meanwhile, with the increase usage of steam engines and their huge requirement of lubricants, demand for oil increased dramatically, which left mankind with no option rather than developing their tools and look for large reserves of petroleum. Surprisingly, recent research has established that the world's first drilling of a well was drilled to the depth of 21 meters which was magnificent for their possessing equipment. It

took place in Absheron peninsula in 1846, in the region near the Caspian Sea. Companies used this method to drill the first world's oil well in 1846. Subsequently, after thirteen years this method was used to drill the first oil well in the united states in 1847(introduction on petroleum geology, Dr. Fereydoon Sabahi, 2009) . Colonel Edwin Drake was the supervisor for this operation and truthfully he was a railway guard and not an engineer, however due to some notions that are not clear , he was assigned the responsibility of the project. This led to the oil booming in the united states. By November 1860, there were 75 wells in the oil creek river valley and more than 500.000 barrels of oil were produced by the end of that year (Geology of petroleum (second edition), A.I. LEVERSON, 2004) .

Compare to the American version of oil industry, there is another one that I will look into in the following paragraph. The beginning of the Russian oil industry dates in 1864, when colonel Aradalion Novosiltsev did the first drilling operation to the depth of 55 meters in Kuban in the Kudako river, by mechanical cable tool percussion equipment. Meanwhile, the first oil gusher was signed up in February exactly two years after the drilling of first oil well, 1866.Global oil production underwent intensive development in 19th and 20th centuries with the invention of diesel and petrol internal combustion engines and their application to industry. In 1859 something amazing happened, a mining engineer used steam engine in order to drill an oil well. It had 45 meters deep, which was 10 meters lower the first well in the Russian subordinate land, and it was operated in Baku in 1872. They developed their own method, which they called '' percussion method" in order to drill their well. It consists of rod, cable and rapid percussion drilling with flushing of the well. Rotary drilling with a circulation flow of fluid to flush the well was applied for the first time in the united states in 1901. In Russia, rotary drilling with flushing was first used in Gronzny to drill a well of 345 meters deep. This method which make the operation quite easier for engineers was invented by Fawell, an French engineer.

However, engineers did not stop there and look for new ways of drilling and soon they realized that doing an offshore drilling will reduce their cost in some cases as well as provide them with more reserves. Due to this phenomenon, On October 1897 the world's first offshore drilling happened. The person in charge of this operation was H.L Williams , who drilled a well on a wooden pier in the Snata Barbara channel in California. He utilized the pier to support a land rig next to an existing field. Due to this evolution, a lot of countries used the same principle and in five year , there were 150 offshore well in the same area. By 1921, steel pier was being used in Rincon and Elwood California to support land-type drilling rings. There are certain stages in the drilling of a well, which will be looked into in the following paragraph (http://www.visions.az/en/news/366/4ca556e3 ,2019) .

Planning

Beforehand of the drilling operation, everything is in the hand of a geologist, whose target is to identify hydrocarbons underground and give a schematic picture of the field underground. For this reason, they will as a geophysicist. The targets of a production well are mainly two things, optimizing production and manage the reservoir drainage. Meanwhile, for an exploration well their target is quite different. They look mostly to confirm the possible hydrocarbon reservoir existence and to study it to some extend. Another well which come into the light is the injection well which has another target. It is used to locate the best point for injection liquid or gas into the permeable layer, which may support disposing of water of gas and or pushing hydrocarbons into nearby production wells. They are so many consideration that an design engineer must take into

account such as, clearance to any nearby wells or they have to even predict either this well will be in the way of the new wells in the future (Foundamentals of petroleum drilling, Dr, Ali zamani, 2014) .

The next step is to understand the well path, which will be done by geologist, geophysicist and petroleum drilling engineer. Then, they assign properties to the subsurface which the well will be going through until it will reach the target. These presumptions are pore pressure, fracture gradient and wellbore stability. Meanwhile, porosity and permeability are also assigned however they are variable due to the different formation in the reservoir. In addition, a well engineer will use these speculations in order to do the case design which is unique for each well. Likely, he will also do a completion design of the well and also the wellhead. Furthermore, a Bottom Hole Assembly is designed and the type of drilling fluid, mud, is choose which can be water base, gas base or in some cases gas base. The most important think to consider is cost and efficiency and it will affect all other options. Sometime several plans will be shown and a discussion will be held in order to choose the most suitable one.

Drilling

This operation as it sound is to dig into the ground. The equipment used for this operation is drilling bit and rods. Firstly, a drilling hole 12 cm to 1meter diameter will be dig in the ground. After the drilling, the casings will be placed in the hole, which have lower diameter compare to the hole. In order to fix the casing inside the whole, cement will be used by drilling operators, however this kind of cement is way different than regular ones and the speed of forming is less. The reason for putting casing in the hole is the phenomenon that it will protect well from overpressure zones and isolate it from other dangerous high pressure zones. It is due to this fact and security that companies are able to drill deep wells into the formations.

In order to drill a well, the drill bit aided by the weight of the drill string above it cuts into the rock. There are different types of drill bit. some cause the rock to disintegrate by compressive failure, while others shear slices off the rock as the bit turns. Drilling fluid, mud, is pumped down the inside of the drill piper and exists at the drill bit. The principal components of drilling fluid are usually water and clays. However , it also typically contains a complex mixture of fluids , solids and chemicals that must be carefully tailored to provide the correct physical and chemical characteristics necessary to safely drill the well and prevent any blowout .Particular functions of the drilling mud include cooling the bit , lifting rock cutting to the surface , preventing destabilization of the rock in the wellbore walls and overcoming the pressure of fluids inside the rock so that these fluids do not enter the wellbore . some oil wells are drilled with air or foam as the drilling fluid(Fundamentals of petroleum drilling, Dr, Ali zamani, 2014) .

The generated rock due to the drilling, which is called cuttings, are swept up by the drilling fluid as it circulates back to surface outside the drill pipe. The fluid then goes through shakers, which separates them from the going fluid into the well. Watching the abnormalities in the returning cuttings and monitoring pit volume or rate of returning fluid are important to prevent Kicks. A kick is when the formation pressure at the depth of the bit is more than the hydrostatic head of the mud above, which if not controlled temporarily by closing the blowout preventers and ultimately by increasing the density of the drilling fluid would allow formation fluids and mud to come up through the annulus uncontrollably.

The piper or drill string to which the bit is attached is gradually lengthened as the well gets deeper by screwing in addition 9 meter sections or joints of pipe under the Kelly or top drive. This process is called making a connection, or tripping. Joints can be combined for more efficient tripping when pulling out of the hole by creating stands of multiple joint. A conventional triple, for example, would putt piper out of the hole three joints at a time and stack them in the derrick. Many modern rigs, called super singles, trip piper one at a time, laying it out on racks as they go.

This process is all facilitated by a drilling rig which contains all necessary equipment to circulate the drilling fluid, hoist and turn the piper, control downhole, remove cuttings from the drilling fluid, and generate on site power for these operations.

FIGURE 1- shows an active offshore drilling rig (http://www.drillmec.com/en/p/modular-drilling-rigs/)

After drilling and casing the well, it must be completed. completion is the process in which the well is enabled to produce oil or gas. In a cased-hole completion, small holes called perforations are made in the casing which passes through the production zone, to provide a path for the oil to flow from the surrounding rock into the production tubing. In open hole completion often sand screens or a gravel pack is installed in the last drilling uncased reservoir section. These maintain structural integrity of the wellbore in the absence of casing, while still allowing flow from the reservoir into the wellbore. screens equipment, which can cause washouts and other problems, particularly from unconsolidated sand formations of offshore fields. After a flow path is being made, acids and fracturing fluids may be pumped into the well to fracture, clean, or otherwise prepare and stimulate the reservoir rock to optimally produced hydrocarbons into the wellbore, Finally, the area above the reservoir section of the well is packed off inside the casing, and connected to the surface via a smaller diameter pipe called tubing. This arrangement provides a redundant barrier to leaks of hydrocarbons as well as allowing damaged sections to be replaced. Also, the smaller section will produce reservoir fluid at an increased velocity in order to minimize liquid fallback that would create additional back pressure, and shields the casing from corrosive well fluids.

In many wells, the natural pressure of the subsurface reservoir is high enough for the oil or gas to flow to the surface. However, this is not always the case, especially in depleted fields where the pressures have been lowered by other producing wells, or in low permeability oil reservoirs. Installing a smaller diameter tubing may be enough to help the production, but artificial lift methods may also be needed. Common solutions include pumping downhole, gas lift and pump

jacks. Many new systems in the last ten years have been introduced for well completion. Multiple packer systems have cut completion costs and improved production, especially in the case of horizontal wells. These new systems allow casings to run into the lateral zone with proper packer / fracture port placement for optimal hydrocarbon recovery. and new material were not able to be discovered by them. Petroleum is also using in petrochemical industry for making material as well as wide ranges of industries to provide their necessities(Fundamentals of petroleum drilling, Dr, Ali zamani, 2014) .

Production

The most important stage of well's period is production stage , and in this period both oil and gas are produced. Meanwhile, by reaching this oil both oil rige and work over rigs that were used to drill the well were moved away. The top of the well is usually outfitted with a collection of valves called a Christmas tree. The duty of these valves is to regulate the pressure of the well and control the flows. Meanwhile, they will provide access to the wellbore in case further completion work is required. From the production tree, the flow goes through a distribution network of pipes ,which leads to refineries, natural gas compressor stations or oil export ports.

As long as the pressure in the reservoir is high enough, the production tree is responsible for the production from the well. If the pressure decreases and it is no longer economically viable, engineer should use another artificial production method which were described in the completion section. The workover process is sometimes required in older wells, they may require smaller tubing diameter, or paraffin removal, acidizing or completion of new zones of interest. These workover processes require rigs, which is called pulling units, completion derricks. They may also had to pull and replace tubing and in some cases do that by using a method called well intervention techniques utilizing coiled tubing.

Lastly, there is the reality that since the depletion drive of the reservoir is decreasing and soon the pressure will not be enough for natural production. Engineers must apply enhanced recovery methods such as water flooding, steam flooding, or co2 flooding may be used the increase the reservoir " sweep efficiency ", which is given for the effect of pushing hydrocarbons out of the reservoir. Some mentioned methods, require the usage of injection wells which its exact location will be chosen by the drilling engineer.

Abandonment

The next stage and the final stage is called abandonment. When a well is said to not have an economic value and it is not provide enough money for continuing the production operation, the will be abandon by workers and company. There are many mathematical formulas for calculation the abandonment time of the reservoir.

When the economic curb has reached, the well life is shortened and the remaining oil reserve is lost.

In this process, the tubing will be removed from the well and well will be filled usually by concrete to isolate the flow path. The fully completion of the reservoir is not necessary and it is quite costly and not required. The wellhead will be cut off and a cap will be welded in place and then they buried it.

Sometimes at the economic limit of a well, there is a amount of oil that is unrecoverable and it should be left in the reservoir. However, if the oil price goes up, companies will be eager to extract the remaining oil that is left underground. In these cases, temporary plugs are used and

well will not be filled with concrete. Right now, there are thousands of abandon wells across the north America and companies are waiting to see what the market will outperform before doing a permanent abandonment.-

In theory, an abandonment well can be bring back to production, however the reentry often proves to be difficult and expensive. Traditionally, cement plugs have been used in order to close a well , however due to the corrosive environment they may be deteriorate.

20 century developments

It was the 20th century, that oil became the preferred energy source and it became the key driver of the major transformation like electric light bulb and automobile. People wanted to possess automobile ownership and demand for electricity grew dramatically. As the result, deman for oil was increased dramatically.

Another major development was related to natural gas, which was burned at site at 1920. Soon, engineers and scientists realized the importance of the material and instead of burning it they provide separators in order to extract it from oil. Furthermore, gas became a more environmentally material for use along with oil. Gas was used for industrial fuel and residential heating and power.

New companies were founded by different countries like UK, Norway and Saudi Arabia.

Since the number of companies and their development plan is quite enormous, I will look into the key major players in petroleum industry. These countries are Saudi Arabia, united states and Russia. Since due to the international embargos on Iran and Venezuela. They are not able to play a major role in the petroleum economy.

In addition, I will look into important oil groups such as OPEC as well as policies of European Union as a major producer of petroleum.

Lastly, I would to say that the world that We are having in terms of advancements has a great debt on oil industry. Since, with reliable energy source scientist were not able to provide energy for their experiments(introduction on petroleum geology, Dr. Fereydoon Sabahi, 2009) .

1.2Future developments

The world depends on oil and gas in order to make sufficient energy for industries, transportation. However, some may believe that oil and gas era is finished and renewable energy are replacing it, which is not correct due to the phenomenon that according to scientist world's dependence on fusel foils is increasing for the next 50 years.
Due to the oversupply, the oil and gas industry entered a crisis period. It was very surprising due to the united states ramping up oil production and growing sense of optimizing for the industry. They industry is much healthier that it was two years ago and the price of oil almost returned to its true value. After the price of oil stayed in the mid 40 and 50 dollars per barrel. Brent crude is now above 60, of course at the time of writing. The industry is recovering from the worst days of the oil business.

However, the crisis the happened was not out of the blue. The energy agency (IEA) gave the possibility of the supply crunch since 2016.Major companies were providing new projects while they were not aware of the possible crisis after that they had to cancel the majority of their projects. Nowadays, there is a less potential supply available and oil companies are looking to boost their production.

The intrinsic volatility in the sectors is the main challenge faced by petroleum major players. Producers need time in order to address the oversupply and undersupply market. They also must provide plans for changing to using non fossil fuels. Due to these problems, oil and gas companies must provide their strategies in order to decrease the risks.
From 1999 to 2008, oil trend price was one of the most trends in the 21th century. The price of oil went through a spike to under 25 dollars per barrel to more than 160 of dollars between 1999 to 2008. With the growing economies like china and India, the demand of oil increased magnificently and due to this phenomenon the price increased respectively. Soon after, a world recession send oil price to a downward fall. The oil priced went down to 53 dollars in 2008. The economical recovery send the price of oil back to 100 dollars and also 125 until 2014 when its price fell down magnificently. There are numerous factors contributed to the 2014 oil recession. The economic growth of china reduced magnificently after 2010 and its low demand for oil had a great impact on petroleum industry. In the beginning of 21th century, major growing countries like Russia, brazil and India had the same fate as china. The same countries that pushed the price of oil high in 2008 has made it to go down during 2014. Due to the high cost of oil, countries like united states and Canada , which their oil was not economical for production were able to start their production. US companies started to produce from Alberta's oil sand. The world third largest reserve. Due to their production, north America companies were able to decrease their import and put downward pressure on world prices. Unfortunately, Saudi arabia's decision to let the price of oil decrease due to not cutting their production share. The middles eastern countries kept their production stable by believing that in long tern they will have benefit. Because of their decision and the face that Saudi Arabia produces oil so cheaply and have the largest oil reserves in the world. It can withstand low oil price for a long time without any threat to its economy. However, extraction methods such as fracking are more expensive and are not beneficial if the price of oil decreases too much. By lowering the price, Saudi Arabia was hoped to make countries like united states and Canada to withdraw from the production plans.
There are long and short goals that companies must looked into and these will be discussed in the following paragraphs.
While the short effect of oversupply may be gone quickly, the aftereffects will continue and companies must keep their main discipline and focus more on productivity improvements and apply new technology. Because of high cost of petroleum while at the same time the price of oil

went down dramatically. Companies were forced to talk with their engineers in order to reduce their production cost , meanwhile they were aware of high loss of their profitable and the focus on productivity improvements and applying new technology. Due to the high cost of oil drilling while at the same time the price of oil went down dramatically. Nowadays, oil companies are pioneers in researching new methods in order to produce oil with law cost of production. Meanwhile, new friendlier environmental methods were used by companies and new machines were bought by them. With these methods, they were able to reduce their production cost, while at the same time increasing the prosperity. Oil is a major economic factor for a lot of countries and increasing and decreasing prices with effect directly their economy. Meanwhile, by using new methods companies are not forced to close their fields due to high cost of production and low profit and in some cases no profit at all.

In the long term purposes, companies must be sure that their business is profitable despite low prices. Due to this phenomenon , they must be aware how their business is profitable in the future and provide the best path to the reduction of co2 emission. The following line graph is about the growth in oil supply and demand. Additionally, they have to utilize friendlier methods of production, same as short term method, and provide more green source of energy. Furthermore, companies should invest their profit in developing new green energies and lowering the cost of developing current methods. Solar energy is promising and the environmental effects is substantially low. Due to this phenomenon, companies can have the future with their current profit and will have a high level of prosperity and profitability in the future. It is undeniable that world will change to renewable energies in the near future and will abolish the fossil fuels.

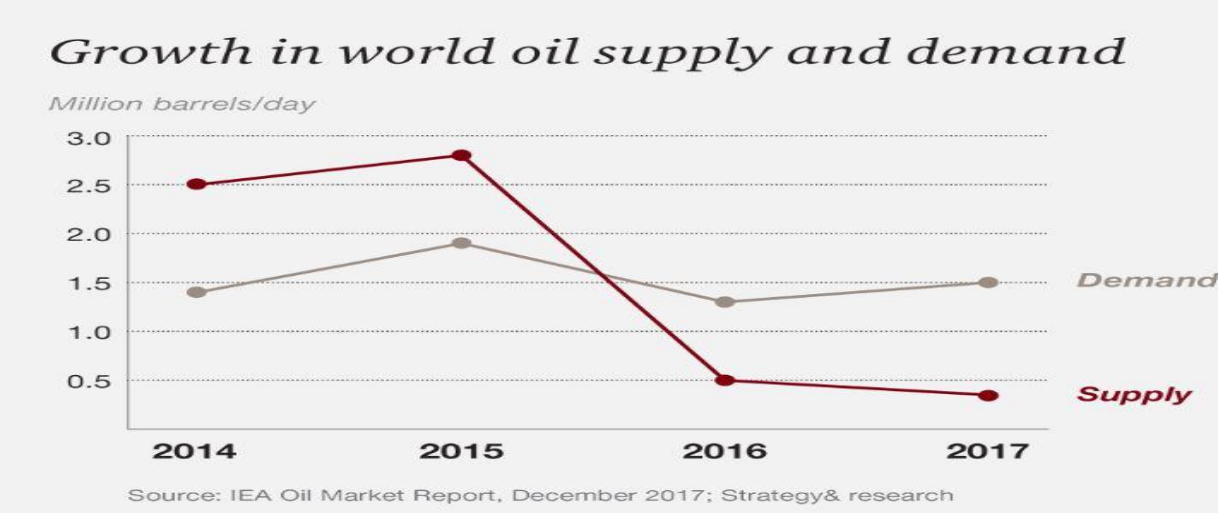


Figure 2 – represents world growth of demand and supply **(IEA oil market report december 2017, strategy and research)**

As we can see from the graph, as the amount of supply increased in 2014 compare to its demand. The value of oil decreased dramatically from 120 dollars to 40 dollars. From 2016, due to the gathering of oil export countries and organizations, such as OPEC. They had decided to decrease the production of the reserve and the results is inevitably caused the oil price to escalate. However, I have to mention that compare to 90s and 80s the dependency of counties on natural gas compare of crude oil increased dramatically. The following graph will demonstrate the difference between these two era.

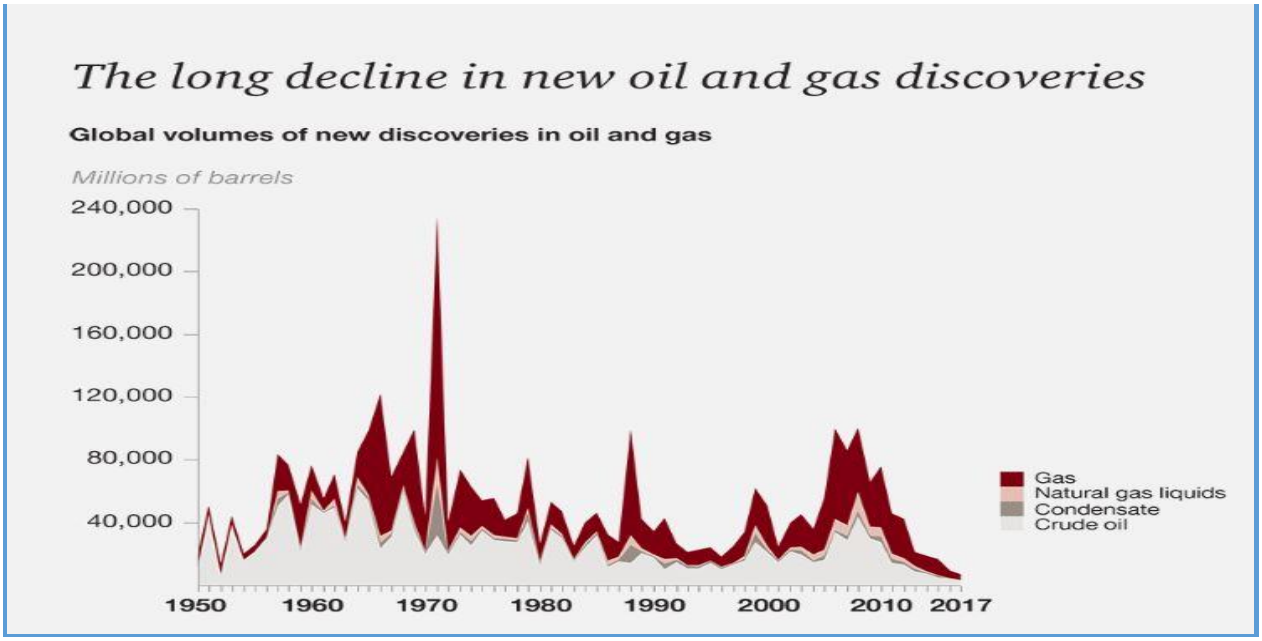


Figure 3 – shows the decline of oil and gas discovery from 1950to 2017 **(IEA oil market report december 2017, strategy and research)**

Furthermore, the industry will grow in the following year, while statistics show increase in demand. In spite of this phenomenon, people deem that oil and gas era is over and soon renewable will supplant them.

On the contrary, as the graph shows the high investment in the developing plans for oil and gas extraction. It is undeniable that a shift to renewable energies is inevitable. More countries are declaring their plans to reduce their co2 emission and in some cases they asked the united nation for submitting a fine for the high co2 emission countries. A Great effort was made inside countries to decrease their emission and in some cases, global agreements such as Paris Agreement were made by countries on the global stage.

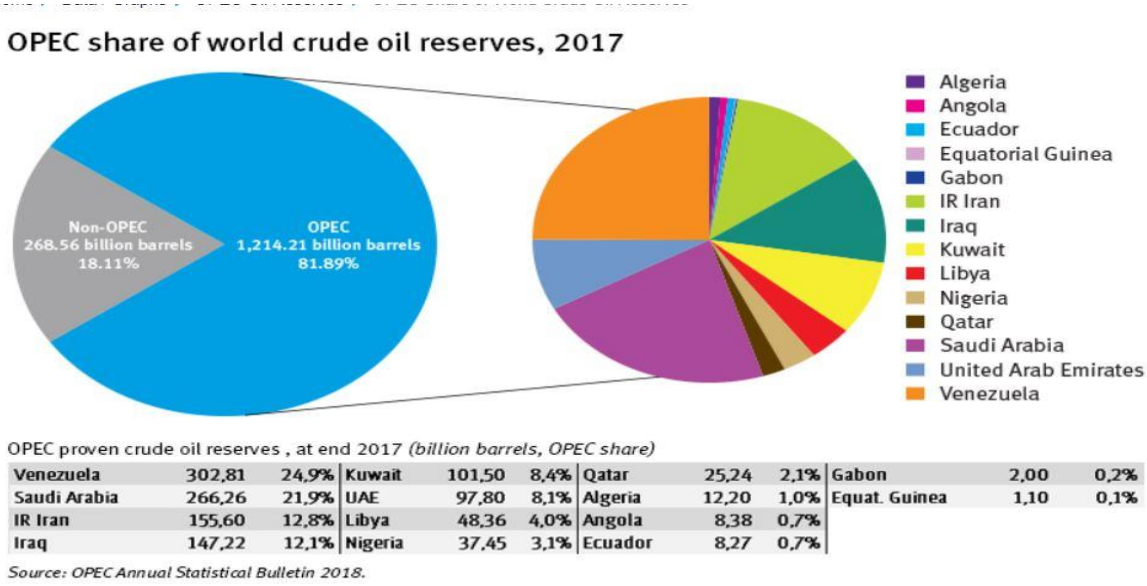
European union is one of the active players in the terms of energy. Due to their lack of possession of oil and gas and their high amount. They are mostly importers of these source of energy. Meanwhile, they are investing a high amount of money in their universities to expand renewable energies and even make them cheaper and more effective. A great effort was the National Renewable Energy Action Plan is a detailed report submitted by members of the European Union in order to develop their renewable energy source in all the states by 30 June 2010. It also contains a detailed map of how the countries should reach its legally binding 2020 shares of renewable energy consumption **(IEA oil market report december 2017, strategy and research)** .

In order to see the truth, we should look at the amount of investments that countries, especially oil counties are putting in the discovery of new reserves and improving their technological aspect. In the following page, I will look for the developments plan for each major oil organizations, such as OPEC and European Union since they are the major consumer of oil.

1.3Major oil organizations

OPEC

The organization of the petroleum exporting countries, which was summarized to OPEC contains of 14 countries. However, it reduced to 13 due to the recent declaration of Qatar that they will leave the organization. This organization was founded in 1960 in the city of Baghdad by five first members, which were Iran, Iraq, Saudi Arabia, Kuwait and Venezuela. They decided to put their headquarters in the city of Vienna, Austria. Their main goal was to make a balance between demand and production in order to sell their products will best prices. By 2018, the 13 country members declared that they have almost 44 percent of global oil production and 81.5 percent of world's oil reserves. OPEC soon gained a great influence on the market and overrun its previous groups such as, seven sisters. Seven Sisters was a group of major oil companies. In 1970's the limitations on oil production made oil price to increase dramatically. In the 1980's , OPEC decided to put production limit for its members, generally , when the production decreases the oil price will increase. In addition, for countries that produce low volume of oil compare to major players their negotiating power must not be so much high, however their membership cost is the same, which is 2 million dollars. Ecuador went out of OPEC because it was unwilling to pay their 2 million dollar share. Also, they though that they should produce more oil which they could not because they were part of OPEC. Although, it rejoined in 2007similarily, Gabon suspended its membership in 1995 and it rejoined in 2016. In May 2008, Indonesia announced that it will leave OPEC when its membership will be expired at the end of that year. Indonesia decision was due to the phenomenon that they became a major oil importer and could not reached their production share. They also rejoined OPEC in 2016 but another temporary suspension of its membership was announced when OPEC asked a 5 percent production cut. Since 1980, representatives from several countries have attended many OPEC meetings as observers. This arrangement serves as an informal mechanism for providing unique policies in the market. They meetings are attended mostly by oil ministries and they meet in Vienna at least 2 times per year. Saudi Arabia because of their impact on the market have the role of de facto in the OPEC. They often have difficulty on green policy decisions because its member countries differ widely in their oil export capacities, production costs, reserves, geological features, population, economic development, budgetary situations, and political circumstances. (https://www.opec.org/about). They were also international incidents related to OPEC. In 1975, Iran prime minister and Saudi Arabia oil minister were kept hostage at their semi-annual meeting by Venezuelan militant , whose name was Carlos the jackal. After two days, all the hostages were released. In 1980, the war between Iran and Iraq force countries to change from oil to coal or nuclear energy. Meanwhile, OPEC share reduced from 50 percent to 30 percent in 1985 (OPEC , iran foreign ministry, 2009). The share of OPEC of world market of oil or generally energy will be showed in the following pie chart.



OPEC proven crude oil reserves , at end 2017 *(billion barrels, OPEC share)*

Venezuela	302,81	24,9%	Kuwait	101,50	8,4%	Qatar	25,24	2,1%	Gabon	2,00	0,2%
Saudi Arabia	266,26	21,9%	UAE	97,80	8,1%	Algeria	12,20	1,0%	Equat. Guinea	1,10	0,1%
IR Iran	155,60	12,8%	Libya	48,36	4,0%	Angola	8,38	0,7%			
Iraq	147,22	12,1%	Nigeria	37,45	3,1%	Ecuador	8,27	0,7%			

Source: OPEC Annual Statistical Bulletin 2018.

Figure 4- demonstrates OPEC share of petroleum world (https://www.opec.org/opec_web/en/data_graphs/330.htm)

According to current estimates, 81.89% of the world's proven oil reserves are located in OPEC Member Countries, with the bulk of OPEC oil reserves in the Middle East, amounting to 65.36% of the OPEC. OPEC Member Countries have made significant additions to their oil reserves in recent years.

As can be seen from OPEC website, the amount of investments is divided into two parts, downstream and upstream part.

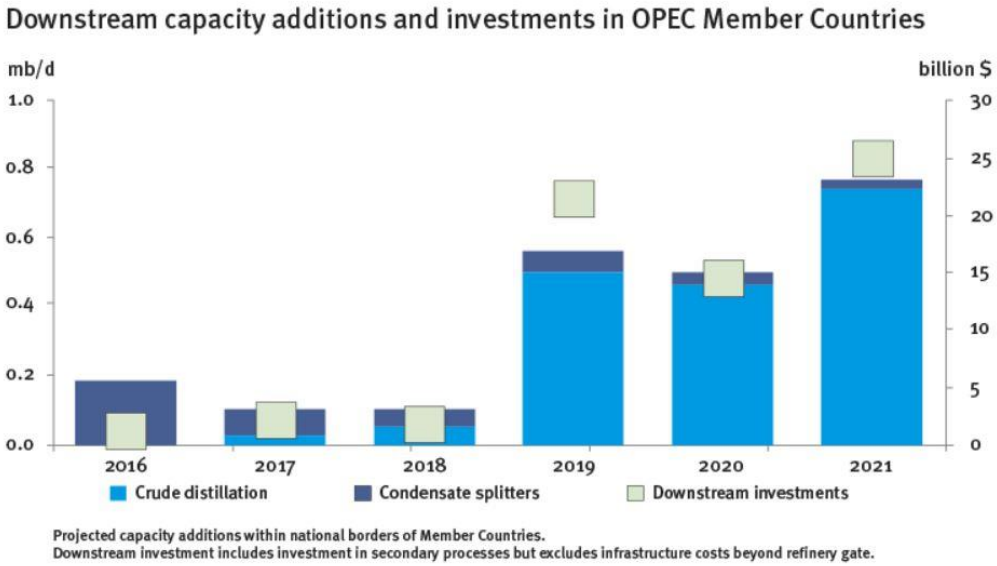


Figure 5 –shows OPEC investment in downstream industries (https://www.opec.org/opec_web/en/650.htm)

Downstream, which stands for petrochemical section of oil and gas industry, capacity will increase to more than 20 billion dollars be 2021 while the amount of investment will increase respectively.

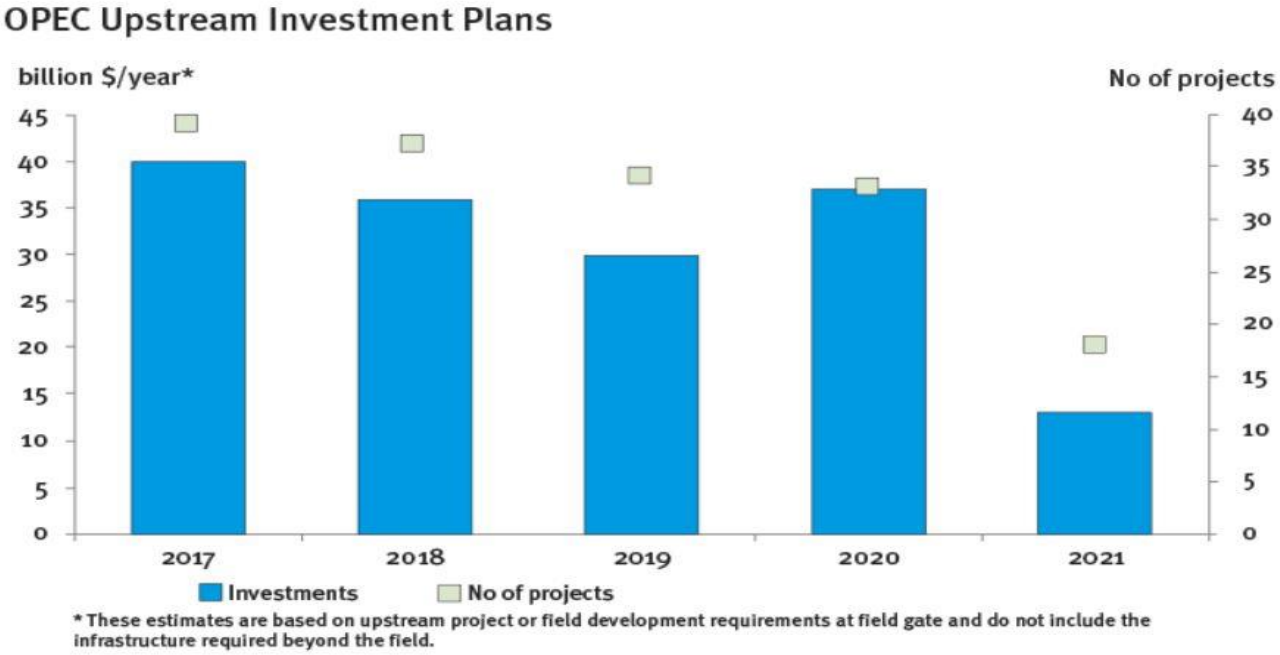


Figure 6 – shows the OPEC upstream investment plans (https://www.opec.org/opec_web/en/647.htm)

Upstream, which is related to drilling section and discovering part of petroleum engineering, will decrease steadily due to the fact that by 2021 most of oil reserves will be discovered and we must put our focus of increasing the efficiency of production part of reservoirs, case like EOR and overall increasing the recovery factor.

In addition, since Qatar declared that they will leave the OPEC it is evident that in terms of petroleum they will not be a major impact since Qatar is the in possess of major oil supplies. However, they have high reserves in natural gas. Furthermore, due to the sanctions by the united states on IRAN. They market was panicking about the lack of supplies but other major companies in the OPEC were able to withstand this impact and United States also was aware of this phenomenon and they also give some counties exemptions from the penalties so they can continue their trades with IRAN. As of May 2019, United states declared that there will be no exception for countries in order to import oil from Iran and due to the phenomenon oil price increased and recently there is a probability of a Full range war between Iran and United states, which will not oil damaged both side, it will also increase the price dramatically. Recently, there was an explosion in one of the United Emirates ports where two ships were sabotage terrorist and several attacks on Saudi Arabia Aramco oil line which made an increase in the price since countries are worried that they will have to buy more expensive in the future and Persian Gulf's is one of the major oil producer regions in the world.

EUROPEAN UNION

The European union ,EU, is a union in terms of economy and political made of 28 members . These 28 members are located in Europe continent. The Area of European Union is 4 million kilometer square and the population of approximately of over 513 million people. The European Union has developed an internal single market by using a laws that apply to all the members. EU policies aim to ensure the free movement of people, goods, services and capital within the internal market. The EU and European citizenship were established when the Maastricht Treaty came into force in 1993. The EU traces its origins to the European Coal and Steel community and the European Economic Community, which was established in 1951.

After world war two, European countries united was necessary and was thought to act like an antidote for the extreme nationalism throughout the continent. In 19 September 1946, the prime minister of England, Churchill, gave a speech at the university of Zurich, Switzerland, he also gave

the idea of United States of Europe. This was the first effort to bring countries together. Firstly, ten countries came together and gradually from 1957 to 1997, other countries joined in. In the following paragraphs, I will look into the Energy policies of the European Union.

Since the amount of oil in possession of the European counties is remarkably law compare to OPEC, however Europe is a major member in terms of technological aspect of future of the industry compare to developments. According to the EU website, Europe is facing rising energy demand, volatile prices, and disruptions to supply. We also need to reduce the environmental impact of the energy sector. To tackle these problems, we need a clear EU energy strategy. So EU energy policy has 3 main goals: 1- security of supply 2- competitiveness 3- sustainability

The Commission has launched plans for a European Energy Union. This will ensure secure, affordable and climate-friendly energy for EU citizens and businesses. Energy will flow freely across national borders in the EU. New technologies, energy efficiency measures and renewed infrastructure will help cut household bills, create new jobs and skills and boost growth and exports. Europe will gradually become a low carbon emission state and more environmentally. It will lead the way in renewable energy production and the fight against global warming. (https://europa.eu/european-union/topics/development-cooperation_en).

EU Energy Targets: The EU has set itself energy and climate targets for 2020, 2030 and 2050.Targets for 2020:1- reducing greenhouse gases by at least 20 percent compared to 1990 levels 2- 20 percent of energy from renewable sources 3- 20 percent of energy efficiency improvements. Targets for the 2030: 1- 40 percent reduction in greenhouse gas emissions 2- at least 27 percent EU energy should come from renewables 3- increase energy efficiency by 27to 30 percent. 4- 15 percent of electricity interconnection (15 percent of electricity generated in the EU can be transported to the EU countries. Target for 2050:1-An 80-95% cut in greenhouse gases compared with 1990 levels. The Energy Roadmap 2050 shows how we could do this .The EU is well on track to meet the 2020 targets:1-Greenhouse gases reduced by 18% between 1990–2012 2-Greenhouse gases reduced by 18% between 1990–2012 3-Renewables share reached 14.1% in 2012, up from 8.5% in 2005 4-Energy efficiency expected to improve by 18–19% by 2020. This is just short of the 20% target. But we can meet the target if member countries enact all the necessary EU laws(https://europa.eu/european-union/topics/energy_en).

1.4Developments plans

As I mentioned before since the number of development plans of petroleum industry are numerous. Looking at the history of oil industry, you will simply see how the industry increased. when Colonel Edwin Drake drilled the first successful oil well in Titusville, Pennsylvania in 1859 companies around the world started to look for oil in their countries and increase their production. Meanwhile, with the introduction of light bulbs by Thomas Edison. The world realizes the necessity for source of energy, which came out to be oil. I will look into three major oil companies, which has the major oil production in the world. Petroleum companies across the world are looking for new reserves due to the phenomenon that the demand is increasing, and more countries are becoming more industrialized. Due to this phenomenon, there are great effort which will be look into across the globe for oil exploration and increasing the recovery factor of old oil reservoirs. In terms of exploration, a lot of companies are looking for oil in the subsea areas, due to the fact that they need to drill less which will decrease costs. Oil production from offshore rigs are quite satisfactory, however new technologies must be invented by companies. Firstly, the amount of corrosion in the sea is much higher that land rigs. As a result, new methods must be devised by scientists to diminish this effect and increase the efficiency of the rigs. Secondly, environmental effect should be under control in the offshore rigs, since there is no place to dump them in the sea. Dumping the waste in the sea, will deteriorate the effect of the ecosystem and will bring detrimental effects for the environment. In the following slides, I will look at developments plans across the globe and new technologies that are developing by major producers of oil and gas companies in order to facilitate the production as well as decreasing the negative impacts of production on ecosystem.

The development stage takes place after successfully completing the appraisal period and before the beginning of the field production. Field optimization included all the activities and processes require in order to develop a field.

I will look into three major companies as I mentioned, which include Saudi Arabia, China and United States. Saudi Arabia alone is the chairman of OPEC and its impact on oil industry is so huge that during the oil crises in 70s by increasing the oil production he made the price so law, less than 20 dollars, so other countries be force to reach an agreement of the amount of production.

Aramco Saudi

Saudi Aramco is a Saudi Arabian national petroleum and natural gas company which is based in Dhahran, Saudi Arabia. It is one of the largest companies in the world by revenue and most profitable company in the world. Saudi Arabia has the second largest proven crude oil reserves and second largest daily oil production. The value of the company is about 2 trillion dollars.

It is all came into action, when SOCAL found the first oil in Dhahran in 1938, a well referred to as Dammam No 7. This well produced 1.500 barrels per day, giving the company enough confidence to continue for oil exploration. On 31January1944 the company name was change from California-Arabian standard oil co to Arabian American Oil Co. The company's headquarters were moved from New York to Dhahran. In 1951, the company discovered the SAFANIYA Oil Field, the world's largest offshore field. In 1957, the discovery the smaller connected oil fields confirmed the GHWAR Field as the world's largest onshore field(https://www.saudiaramco.com/en/who-we-are/overview/our-history) .

In 1975, the Saudi Arabia second five-year economics plan included a Master Gas Plan. Natural gas would be used to generate power, rather than flaring the gas. The plan counted on using the associated gas. This company belongs to the royal family of the Saudi Arabia however recently they declared that they will publicize the company and let other have share in the company.

Unfortunately, the company had the leadership in the companies with the highest level of co2 emissions globally since 1997 with more than 1.707 million tons of emission in 2013. It is almost 3.4 percent of worldwide anthropogenic emission. However, recently more environmental methods have been used and companies is decreasing its emission.

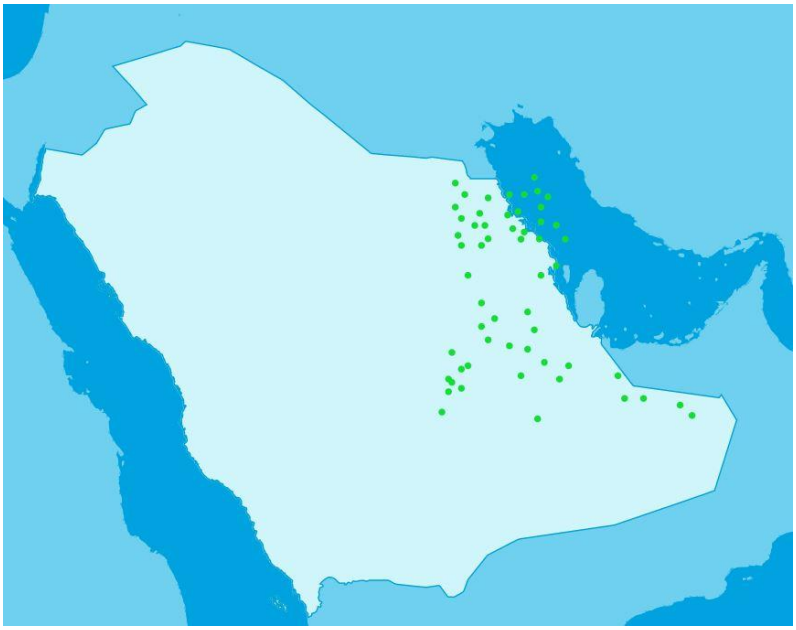


Figure 7 – shows the number of active wells in Saudi Arabia(https://www.saudiaramco.com/en/creating-value/products/oil)

In addition, they declared that they will increase their exploration into subsea area in the Persian Gulf. However, they are not just looking for oil reservoirs and since gas proved to be profitable and more clean energy since the amount of co2 emission is less than oil. There were able to find some gas fields in the country, which will be shown in the following maps. Saudi Arabia plans for development will affect all the world since its impact is significant.

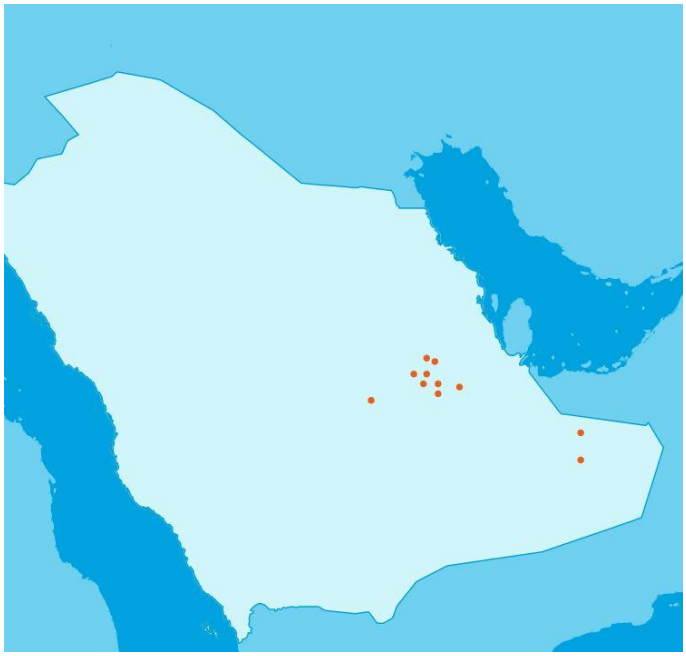


Figure 8 – shows the number of new oil wells in the country of Saudi Arabia
(https://www.saudiaramco.com/en/creating-value/products/oil)

The major importance of this map is that they can even go further to find more sustainable and easy reachable reserves in the sea. The following map shows the developments in the gas fields.

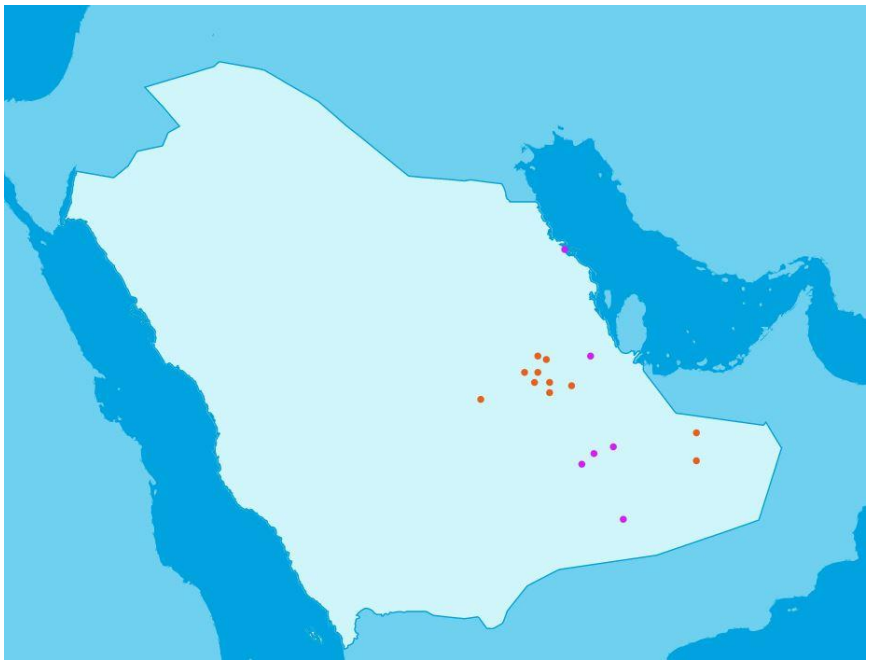


Figure 9 – demonstrates the number of active gas well in the country (https://www.saudiaramco.com/en/creating-value/products/gas)

This company has 70 projects under development and they are investing 414 billion dollars.

Sinopec

Sinopec oil company is the second largest oil company in the world has increased its production in both gas and oil in the recent years. In addition, there were able to discover new oil and gas reservoirs to secure their future as the main producer of oil and gas. in 2017, their new-added oil reserves reached 210 million tons. Meanwhile, their gas reserves reached to 251.1 billion m3 and their possible hydrocarbon reserves reached 265.6 billion m3.

OUTPUT OF OIL & GAS

	2017	2016	2015	2014	2013
Crude oil (million tonnes)	**35.05**	35.66	41.74	43.78	43.78
Natural gas (billion m^3)	**25.74**	21.59	20.70	20.17	18.70

Table 1 – shows the oil and gas production of Sinopec company
(http://www.sinopecgroup.com/group/en/business/InternationalOperation2012/)

This company is focusing on scaling up new reserves and developing economical reserves. They are focusing mainly risk exploration while at the same time they do 3D seismic exploration. So far, they were able to find 3 major discoveries, 14 new discoveries and 20 commercial discoveries. They increased the success of drilling of well by 9.8 percent and appraisal wells by 10.2 percent. As can be seen, they are reducing their expenses by putting their effort on making new technologies, which will reduce the error of drilling a wrong hole.

In the terms of shale gas, they made great breakthrough to optimize capacity of their facilities in Jianddong and Pinggiao for fueling phase 2. The increased their shale gas production to 10 billion m3 as well as introducing new measures for cleaning pipes.

In terms of conventional gas, they have made great progress in made their facilities in Hanginingi AND Dongpo of west Sichuan. They have increased production in gas fields like Puguang , Danuidi , Yuanba , Songnan and Yakela . Total conventional gas production was 19.43 billion m3 with an increase of 3.06 billion m3.

They used the oil increment opportunity for implementing their measures for be sure of their profit and keep their production level stable. In case of new facilities, they are strongly focus on building profitable production capacity carried out rolling exploration and reservoir assessment.

In the terms of improving the existing facilities, they increased the quality and efficiency of mature field and improve their reservoir characterization measurement. Their technique of production is to use low cost technologies and decrease resources and energy usage. In terms of project related to EOR, they upgraded their water quality. Natural decline rate and operating cost both dropped (http://www.sinopecgroup.com/group/en/business/InternationalOperation2012/).

EXXON MOBIL

Exxon Mobil is an American oil company which is based in Irving, Texas. Its root comes from John D. Rocketfeller's oil company, which was formed in 1999 by associating of Exxon and Mobil. This company is the second company in terms of revenue and is active across the glove. However, they are mostly active in the Gulf of Mexico, where has the second oil reserves in the world after the Persian Gulf. From 1996 to 2007, their place varied from first to sixth largest publicly traded companies. The daily production of company in 2007 was 3.921 million BOE but it is still smaller that national companies across the globe.. In 2008, this was approximately 3 percent of world production (https://corporate.exxonmobil.com/Company/Who-we-are/Our-history) . Exxon Mobil is also a refiner and it is the largest refiner in the world a title that was also associated with standard oil since its incorporation in 1870 which helped Rocketfeller to build his empire.

In 1989, company face a lot of criticism due to the oil leakage in Alaska, which was one of the world oil spill in terms of damage to the environment. Recently, they are taking more environmental friendly approaches. The most important thing about the Exxon Mobil is the fact that they are connected to any government and still they produce 3 percent of the world's oil and 2 percent of the world's energy

As I mentioned, the Exxon Mobil environmental record has faced it with a lot of criticism and in 2018, American corporations emitting put the company in the tenth top emission of air pollution. Meanwhile, also company policy brought a lot of criticism since they spend less than 1 percent on research and developing new energy, which, according to the advocacy organization cares, is less than other leading oil companies. Also, they funded research mainly in the line of developing public scientific approach. They also denied the effect of climate change and they were also considered to be the leader. However, In 2014, Exxon Mobil publicly acknowledged climate change risk.

Unfortunately, the company funded organization opposing the Kyoto protocol and they were seeking to influence public opinion about the scientific consensus that global warming is even caused by fossil fuel. They also cases related to human right In Indonesia which after a long terms of denial and court session ended. The company has a huge politic power and even determine America's foreign policy. Their revenue is so huge and they had gain relationship with a lot of countries across the globe. Due to this phenomenon, this statement is not completely wrong.

In the case of production, they like other companies are looking for making production easier and decrease the production costs. The company has a great plan for 2040 to predict future related technologies. The main focus is , of course, on their energy section . However, after seeing how the technology improved over 50 years ago the types of deep water and directional drilling , they also trying to improve their R&D research plan. (EM-Corporate-Energy-for-our-Future.pdf) .

chapter 2
Selected technologies

2.1History of drilling

Combustion engine was developed in late of 19th century and before that the main method for drilling was manpower or using animals. The Rotary method for drilling a well has its root back to 500 BC, where in china during the Han Dynasty they used this method They used this method for extraction of natural gas in the SUCHUAN province of china. The early methods for drilling was quite simple and they did not require an advance technical skills. They were mainly base on availability of heavy iron bits and bamboo poles. The demerits of this method was the face that they could not go deeper than 100 meters by 10th century, however by 16th century Chinese were able to dig a well up to 2000 feet deep. Americans used this method and drill the first petroleum well in Pennsylvania in 1859 by using a small steam engine.

In 1970s, outside the oil and gas industry, pneumatic reciprocating piston replaced roller bits and became essential for most of shallow wells drilling. They are now only being utilized in certain scenarios where rocks pass other methods. Rotary drilling system is much faster and more efficient and is now widely used across the glove.

In the early time of oil exploration, drilling derricks were mainly semi fixed. They were left there after the drilling and completion operation. Nowadays, the drilling derricks are quite expensive and each have their own characteristics and most importantly they are movable, which reduces the cost of doing a drilling operation. For drilling or bore piles, we can also use small movable drilling derricks.

They are many types of drilling rigs and designs which is specified to each well and most of the rigs have the capability to switch or combine different technologies as required. Most drilling rigs are categorized in the one of the following attributed:

1-Mechanical 2- Electric C 3- Hydraulic 4- Pneumatic 5-Steam.

In terms of height, it is divided into four categories whether single, double, triple rigs. In addition, there are several methods can be used to drill a well such as Rotary table, top drive, sonic and Hammer. The most widely method for drilling a well is Rotary table method and top drive comes in the second place, however it is more comfortable and more economic for companies to use in terms of decreasing the number of require crew and increasing the efficiency. On the contrary, top drive system is expensive and implementing it at first will cost companies a huge amount of money which some are not willing to undergo. As a result, they would like to stay using the rotary table systems which is not outdated but the efficiency and the number of people needed to do drilling is very high.

The new term in the drilling engineering is directional drilling, which was introduced to the world and since then is used to drill a horizontal wells or mainly wells with a level of trajectory. It is mostly categorized into four groups. The reason for developing this technology was due to the phenomenon that sometimes the oil field cannot be reached directly due of being under a construction or in some cases being inside the sea. As we know, the cost of offshore drilling is way higher compare to land drilling. Due to this fact, companies are able to drilling a well from the land and enter an oil field inside the sea.

Many companies enabled this technology to become more productive. Probably, the first necessity was the realization that oil well or water wells are not necessarily should be vertical. This method will increase the exposed section length though the reservoir by drilling through the

reservoir at an angle. It will make it possible to hit a reservoir where vertical access is difficult or not possible and etc(drilling engineering , Alireza moazen , 2013).

2.2New technologies

Petroleum is a vast industry and the number of innovations are hugely massive . So, covering all the innovations that are happening at this very moment will be an impossible task. I had to select an interested field and go deep into its innovations. I tried to make my thesis base on the reality that is inevitable for all the industries including the petroleum industry. As everybody is aware of the number of workforce is decreasing and the reality of human error is a factoring that impacting all the formulas whether industrial engineering or risk analysis. Due to this phenomenon, all the major companies are attempting to supplant their work forces by robots. By this way, not only they will have cheaper work force, they will be able to reduce the chance of any unprecedented accidents, which will cost them great budget as well as destroying their reputation. After all, everyone in petroleum industry knows about the petroleum leakage in Gulf of Mexico and the impact of minimizing the reputation of British oil company, BP.

Due to the mentioned I put my focus on robotics and company innovations in this field. Mostly, I put my effort on robotics related to drilling operations. As we call know, since the first oil well drilling, the number of Roughnecks (an expression used for workforce that I working on the drilling rig) is increasing and it is inevitable since they have to be trained greatly due to their sensitive job. Also, they will receive a great salary because of the high risk of danger. On the contrary, a robot does not require any training and they only need an input, which can be done through computer. In addition, they do not need a salary since they are not humans. All these reasons are sufficient to spend and put all company budgets to introduce new technologies related to robotics(https://www.robotics.org/blog-article.cfm/Robots-in-the-Oil-and-Gas-Industry/40) .

In the following paragraphs, I will look into key aspects of my selected technology and I will also look into some new innovations in petroleum industry.

Robotics technology is increasing rapidly and base of many speculation the future market of this field will be 135.4 billion dollars. It is inevitable that robotics is making productivity and operation costs less. In the past decades, there were some periods that oil price exceeded 100 dollars per barrel. Other than a little decrease in the price of oil during the great recession, the times was gold for petroleum industries. It was too good for them that the operational productivity was ignored by companies. However, by the mid of 2014 when the priced dropped magnificently and stayed low after that. Companies realized the huge inefficiencies that is existing in their industry. This made them to invest greatly in developing robotics and automation of oil and gas industry was prioritized by the company board. As I mention, one of the well-known usage of robotics in oil and gas industry is in the Roughneck section. The Iron Roughneck robot, which was developed by the national oil well Varco Inc, is a true example of company effort to make automation possible as soon as possible. Other applications include remote-operated aerial drones, automated underwater vehicles, robotic drilling and much more..

Unfortunately, the industry is not quick to adopt automation technology because of its old age and the huge impact on cost of changing devices. However, there are some companies that are trying to decrease their costs so deeply into profits. Another aspect of using robotics is the phenomenon that oil and gas industry is dangerous and robotics make the workplace safer for everyone(https://www.oilandgaseng.com/articles/robots-role-in-the-oil-and-gas-industry/).

The iron roughneck robot, which was invented by Varco inc, is a great example as I mentioned before. It is in use in the industry for make-up and break-out system for drill string connections. It will increase the safety, by ensuring protection to drill pipe threads, and by providing reliable make-up torque to drilling connections. of course there are merits and demerits associate to this device. Both advantage and disadvantages will be given in the following table(https://www.nov.com/Segments/Rig_Technologies/Rig_Equipment/Land/Iron_Roughnecks/Iron_Roughnecks.aspx).

Figure 10- shows the iron rough neck device by varco inc
(https://www.nov.com/Segments/Rig_Technologies/Rig_Equipment/Land/Iron_Roughnecks/ST_80C_Iron_Roughneck/ST-80C2_Iron_Roughneck.aspx)

Here are the benefits of this robot:

Features/Benefits

Gateless torque wrench
Unparalleled make-up repeatability
Spinning wrench automatically counter-rotates to seat threads, then safely spins-in
Economy of rig floor space- no hanging tools
Enhances crew safety- hands off pipe

Also there are some specification that are specified to this device:

– Specifications

Specifications		
Weight		12,100 lbs (5,680 kg)
Four-Roller Spinning Wrench		SSW-50
	Size Range	3 1/2" drill pipe 9 3/4" drill collars
	Spin Torque	2,000 ft-lbs (2,710 Nm)
Gateless Torque Wrench		TW-102
	Size Range	3 1/2" drill pipe 9 3/4" drill pipe
	Make-up Torque	100,000 ft-lbs (135,580 Nm)
	Break-out Torque	120,000 ft-lbs (162,700 Nm)
	Tilt angle for moushole make-up	3" - 7"
Hydraulic Power Requirements		2,000 psi (135 bar) for torquing up to 8" O.D. drill collars 2,500 psi (170 bar) for 8 1/4" to 9 3/4" O.D. drill collars 45 GPM (170 L/min), closed-center system
	Filtration	12 micron
	Maximum Oil Temperature	180 degrees F (82 degrees C)
Installation Kits		-Four 10 ft. sections positive-drive cog rails -Adapter plate for 37 1/2" or 49 1/2" rotary tables (hinged) -Electric and fluid service look kits -Derrick interface plate assemblies -Control Stations

Table 2 – shows the characteristic of iron rough neck device

2.3 Impact of selected technology

The only industry was amazed of the impact of robotics in their business, whether on land, offshore and deep water operations. Robotics set new standards in quality, safety and efficiency. They are major companies, nowadays, that are working on drilling systems. However, most of the robots worked mainly by mimicking human activity such as, hydraulic arms that moves drilling pipes.

Another important feature of robots that is quite important is the phenomenon that they are able to lift heavy objects and do not have limitation like humans. They are mostly capable of lifting weights up to 1500 kg and the height of three meters.

They are a lot of applications of robotics in drilling engineering and I will give some of them here. These application include drones, automated underwater machines, drilling robots and more. In some cases robotics are helping in the terms of cost like robotics related to downturn of an oil rig. Unfortunately, as I mentioned many oil and gas companies were not quick to adapt this technology while others were and they made a great profit. oil and gas drilling is dangerous work and robots make the workplace safer for everyone. Learn more about how robots improve safety.

The long term goal of this technology is to create a fully automated environment. There are merits to the invention and it will be looked into in the following paragraphs.

The first and mostly important benefit that is clearly important for the investors are the decrease of production costs. A quick return on investment outweighs the initial setup costs. with robots, the speed increase which will impact production. Meanwhile, since robots do not require rest like humans the shorter cycle times is achieved, which will increase efficiency and to continue work at a constant speed without pausing for breaks sleep, or vacations and ultimately has the potential to produce more in a shorter time than a human worker. In addition, the quality and reliability is increasing since it ensures by their manufacture that their mistake is way lower than human in drilling operations. Repairs are few and far between and due to this phenomenon the drilling operation will not be interrupted that much.

Furthermore, by decreasing a footprint of a work area by automating parts of your production line, you can utilize the floor space for other operations and make the process flow more efficient in the rigs. Robots are so accurate that the amount of waste in the operations will be reduce substantially and this will lead to reduce in costs of drilling. An example is the fact that during the tripping out and in operations, a huge amount of mud is waste however with using robots this waste will likely to reach even 0 percent.

Another important advantage of Robotics is related to safety. workers are move to supervisory roles where they no longer have to perform dangerous applications in hazardous settings. Improving worker safety leads to financial savings with fewer healthcare and insurance concerns for employers. Also consider quality and customer satisfaction, which means returning customers and more business.

They are also demerits for this big steps on rigs which will look into. firstly, the initial investment to integrating automated robotics into your business can be significant, especially

when business owners are limiting their purchases to new robotic equipment only. The cost of robotic automation should be calculated in light of a business greater financial budget. Regular maintenance needs can have a financial toll as well. Incorporating robots does not guarantee results devising a specific production plan from the beginning to the end is absolutely crucial.

Mainly, the most important disadvantage is the reality that all the employees will require training for programming and interacting with the new robotic equipment. This will normally take time and financial output. Fortunately, in long turn this huge cost will be recovered however companies should not consider a quick return of their investment since it will need time for payroll.

chapter 3

what is patent and how to use patent data

3.1History of patent

The world patent originates from the Latin Patere, which means “to lay open”. The history of patent was start in 1474 with the venetian statue. However, they are some evidences related to patents that bring its root to ancient Greece. Mostly, in the city of Sybaris , which is locate now in the southern part of Italy, people were encouraged to innovate new refinement and possess the right for their innovation for one year. Meanwhile, in the middle ages in England the patent was granted by king. An example of this is the patent made For John Kempe and his company for instructing English in a new industry. These letters provide the mentioned name with the power to rule single handedly to manufacture a certain good or provide particular service. Another example, is the letter that was given to Utynam a Flemish man for twenty years right for his invention from king Henry IV in 1449.

In Italy, the first patent was awarded by the Florence republic in 1421 to Fillipo Brunelleschi, who received three year patent for a barge with hoisting gear that carried marble along the Arno River. Meanwhile, Venice was also has a system for granting patent for 10 year period in 1450 and they grand right to inventor for his invention, which protected him from any infringers. Mostly, they were related to glass making industries.

The idea of patenting was spread by Venetians people and wherever they went, they give this idea to other nations. However, it was the King of Henry II of France who gave the idea of publishing the description of an invention in a patent in 1555. Patents was given by monarchy or by other instituitions.(https://www.sciencedirect.com/topics/engineering/patent-system).

In England, the royal family used this power to raise power for their crown and make people to pay for them. However, it was widely abused because crown was given rights for every common good. As a result, court curbed king power to give patents. For example, James I was forced to demolish all the patents that he signed and he declared that patents are only for projects or new inventions.

Patent is an intellectual property which give its owner the rights for a specific device or mechanism. Patent will prevent any coping of the mention device and even protect its mechanism from copying. This right includes selling, making, using and it usually has a certain period of time, usually 20 years.

Nowadays, the system is different however the idea remained the same. The world intellectual property organization was set a goal to improve the worldwide protection of both industries property and copyright material. This organization was established in Stockholm and commenced its operation in 1970 exactly three years after its foundations. They put their headquarters in Geneva, this organization can be traced back to 1883 when 14 countries signed the Paris convention for the protection industrial property. Another organization is The United International Bureau for The Protection of Intellectual Property (BIRPI) which was based in Bern, Switzerland. In 1960, BIRPO moved their headquarters like WIPO to Geneva. WIPO has two duties protect the intellectual properties and provide cooperation between other intellectual unions. Nowadays, 180 countries acknowledge WIPO and follow its laws. The also held conference and discuss their problems with the member countries.(https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3632996/).

The patent possession procedure differs depend of countries and the location that the invention was made. Due to the World Trade Organization's (WTO), patents should be available in WTO member states for any invention, in all fields of technology.

3.2PATENT REGULATIONS

The cost of making a patent differs from country to country and may even change upon the complexity of the invention, and also the type of the patent. The average cost of patent in Europe for 10-year-old period is 32 thousand euro in 2005. Meanwhile, in 2008, the cost was something around 10 to 30 thousand dollars per patent. The are some cases that will lead to court in order to resolve the situation, however 95 percent of patent litigation are settled outside of courts.

The layout of each patent is quite simple and it will be given in the following paragraphs.

Front page

It is the same as a title page of a book. A patent should also have a front page and it has to give bibliographical detail.

An abstract

As it name applies, it gives summary about the patent and gives the most important key point of the patent that was patented.

Opening statement

In the opening statement the problem will be given.

Background information

It gives background information about the problem and how it was solved.

Description of the invention

Explain the invention stages and demonstrates how it is working.

Claims

The claim gives what are the aspect of this patent and how it is new compare to other patents.

Illustrations

Each patent depending on its application may possess illustration to simplify reading it and explaining it to others.

Search report

Since there are a lot of patents, in this section information will be given how this patent is not new and there are some related. In this section, claims will be discussed. Some are quite useful.

INID codes

In this section, there are some numbers that will be given and they identify bibliographic elements in patent specification. These numbers may be given also on the front page.

Each patent will be assigned a code, which will be shown that in which fields they are related too. In the case of petroleum drilling engineering E21B is the major international patents classification (IPC) code, which is related to any innovations in petroleum drilling engineering. However, it is inevitable that in the case of robotics related to petroleum engineering we must combine it with different IPC codes. I choose these following codes, B25J, B29C, B28B. Also, I choose the codes related to drilling bits which is a subsection of E21B 10/100. By using these codes and by using the PATENT PLATFORM, I was able to get the assigned county and all the patents related to robotics in petroleum engineering. In addition, since the number of patents were massive, I had to select a time period which in my case is from 2005 to 2019(https://www.bl.uk/business-and-ip-centre/articles/what-is-a-patent) .

chapter 4

methods of patents data selections

4.1International patent classification

The international patent classification is used, nowadays, in 100 countries in order to classify patents in a logical manner. This system was created under the agreement which was made in 1971 in Strasbourg. It is one of the number of treaties that is created by the WIPO and the classification is updated on a regular basis as the technology improves. The updates will be done by the number of experts, who consists of representatives of member countries while there are observers from other organizations.

Each patent publication will have at least one symbol which is related to the inventions and its field. Each classification symbol is of the form A0108 1/100. The first letter represents the relating section and then it is followed by a two-digit number which represent the class. The final letter will give the subclass and it is followed by a three-digit number

These are the main group of patents:

A: Human Necessities
B: Performing Operations, Transporting
C: Chemistry, Metallurgy
D: Textiles, Paper
E: Fixed Constructions
F: Mechanical Engineering, Lighting, Heating, Weapons
G: Physics
H: Electricity

The base of international patent classification was formed under the European convention on the international classification of patents for inventions. In 1968, the first edition became effective and it consists of 103 classes, 594 subclasses. In compare to WIPO, which has 129 classes, 639 subclasses and 7.314 main group. Meanwhile, it has 61.397 subgroups.
The classification was updated each five years until their seven edition until the eighth edition which came in 2006. The merit of eighth edition was the fact that gave patent offices to choice between s simpler to implement rather complex ones.

4.2SELECTION OF CODES and method

Since my thesis was on the basis of drilling engineering I had to choose codes related to drilling codes and the usage of robotics in drilling operation. As a result, combination of codes was inevitable and I had to do this. The main IPC code of drilling operation is E21B which stands for drilling operation whether in mining and petroleum industry. E21B stands for Earth or rock drilling (mining, quarrying, making shafts, driving galleries or tunnels, obtaining oil, gas, water, soluble or melt materials or a slurry or minerals from wells. This subclass covers, primarily equipment for drilling of earth or rock in their natural formation, similar equipment for drilling of man-made structures in situ example of road surfaces or concrete structures. This subclass does not cover, hand-held drilling machines example for domestic use and drilling equipment for manufacturing operations. Also, compositions for drilling of boreholes or wells or for treating boreholes or wells, which compositions are covered by group e.g. compositions for enhanced recovery methods for hydrocarbons.

In addition, I choose B25J which stands for manipulators, chambers provided with manipulation devices (robotics devices for individually picking devices. Generally, this code is look into robotics in doing industrial operation whether petroleum or not. However, combining these IPC code with E21B showed the robotics related to petroleum engineering especially drilling section that I looked into.

Meanwhile, I found two other IPC codes, which were B29c and B28B, these two IPC codes were also related to robotic usage in industries and again making an combination with E21B gave me the accurate results of patents that were on progress in petroleum drilling section.

After the section of IPC codes, I looked into patent system which calls DERWENT WORLD patent Index, which I will give introduction about its history and usage in the following paragraphs.

The Derwent world patents which I took my patent information from is a database containing patent applications data and it is form of 44 world's patent issuing authorities. Each record in the database is defined by a patent family. At this point, the data base has 20 million inventions and each year million new inventions are added. The number format of dataset was changed in 2008 to allow 3.6 million records per year be added to the system. The previous system gave on 1 million adding permission.

In the following table after looking into the Derwent patent system, I was able to find 1165 patents. Since for looking into the patents, I had to put a time period after consulting my supervisor. I selected from 2000 until 2019.

IPC code combination	Number of patents
E21B +B25J	236
E21B+B29C	826
E21B+B28B	105
TOTAL	1165

Table3 – shows the selected IPC codes and number of patents that were found related to petroleum drilling robotics

However, since there was a limit on the number of patents for analysis and 1165 patents were not sufficient. I decided to do also another analysis in the field of innovations in drilling bits, which were surprisingly high compare to robotics in petroleum engineering.

IPC CODES	NUMBER OF PATENTS
E21B 10/100	5349

Table 4 – demonstrates the patents that were found related to petroleum drilling bits

Again, I had to curb my timeframe and I looked into patents from 2000 up to now. in the following chapter I will look into the analysis this Data in the terms of application country, application year, assignee and IPC codes analysis.

chapter 5
Analysis of data and results

5.1Analysis of application year

In this section after sorting the patents of each section according to their application year. I was able to count each year and find the exact percentage of each one of them. I divide them for each IPC code alone and then find the total percentage both for patents in robotic and drilling bits.

In the case of B28B IPC code, I was able to reach the following results which will be shown in the following table.

Application year	Number	Percentage(%)
2000	0	0
2001	2	1.90
2002	0	0
2003	1	0.952
2004	4	3.80
2005	19	17.59
2006	2	1.90
2007	5	4.76
2008	5	4.76
2009	5	4.76
2010	5	4.76
2011	6	5.71
2012	2	1.90
2013	1	0.952
2014	8	7.61
2015	14	13.33
2016	14	13.33
2017	8	7.61
2018	4	3.80
2019	0	0
Total	105	100

Table 5 – shows the application year analysis with their percentage for the ipc code B28B .

Meanwhile, I did a bar chart which will show the percentage of each year in the mentioned IPC code.

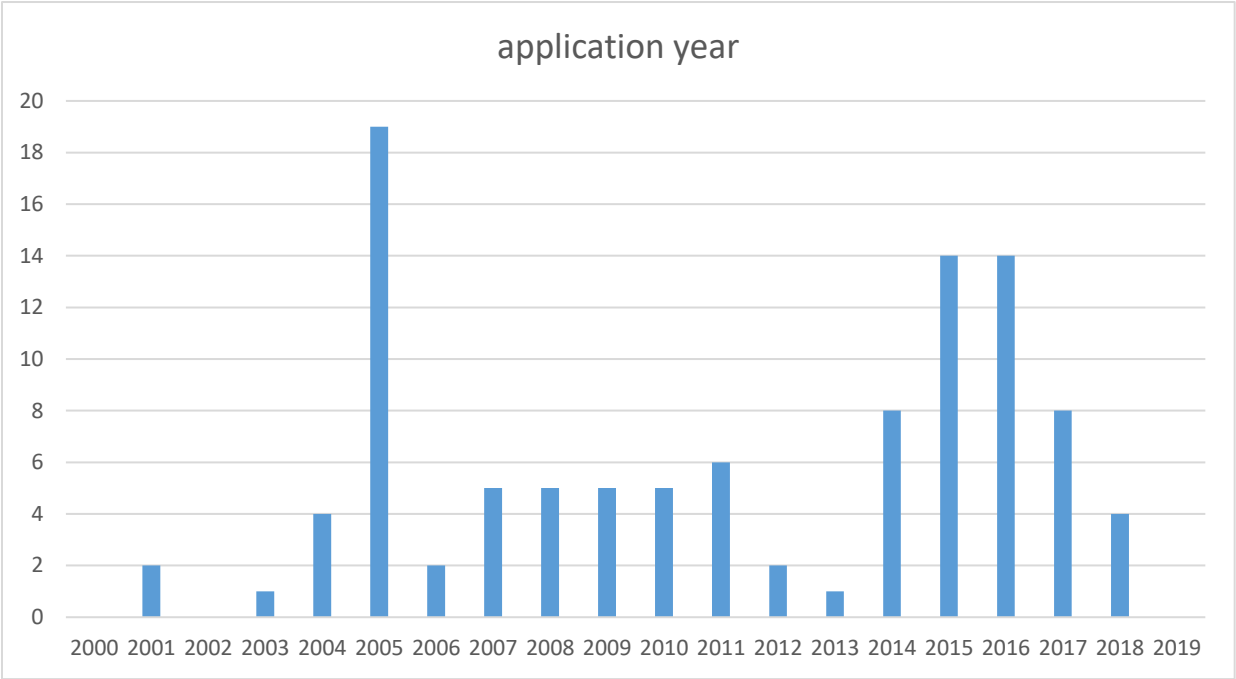


Figure 11 – shows the number of each year patent for B28B IPC CODE.

As can be seen year 2005 has the highest percentage with 2005 following with the year 2015, 2016 and 2014. The majority of patents were done in 2005 while in the 19year period the least number of patents was in 2000 with zero. Now, since we are at the beginning of 2019 I was not able to find any patents until July.

Furthermore, In the case of second IPC code B25J. I did the same survey and reached the following results.

Application year	Number of patents	Percentage(%)
2000	6	2.54
2001	9	3.81
2002	4	1.69
2003	5	2.11
2004	9	3.81
2005	7	2.96
2006	1	0.42
2007	6	2.54
2008	12	5.08
2009	14	5.93
2010	14	5.93
2011	6	2.54
2012	10	4.23
2013	19	8.05
2014	24	10.16
2015	38	16.10
2016	22	9.32
2017	19	8.05
2018	11	4.66

2019	0	0
Total	236	100

Table 6 . shows the number and percentage of IPC CODE B25J , which is related to petroleum drilling robotics

As can be seen, 2015 has the highest percentage of patents with 16 percent while followed by 2014 and 2016. Again in the case of 2019, I was not able to find any patent until the date of writing my thesis. However, the least amount is related to 2006 with only 1 patent.

Lastly, in the case of IPC CODE related to the robotics. I did the last analysis on B29C code and gained the following results.

Application year	Number of patents	Percentage(%)
2000	32	3.87
2001	15	1.81
2002	30	3.63
2003	41	4.96
2004	47	5.69
2005	32	3.84
2006	18	2.17
2007	46	5.56
2008	28	3.38
2009	32	3.87
2010	23	2.78
2011	51	6.17
2012	54	6.53
2013	59	7.14
2014	100	12.10
2015	73	8.83
2016	73	8.83
2017	49	5.93
2018	23	2.78
2019	0	0
Total	826	100

Table 7 – demonstrates the percentage and number of patents for IPC CODE B29C

As can be seen, 2014 has the highest percentage with 12 percent while 2001 with only 1.81 percent has the lowest.

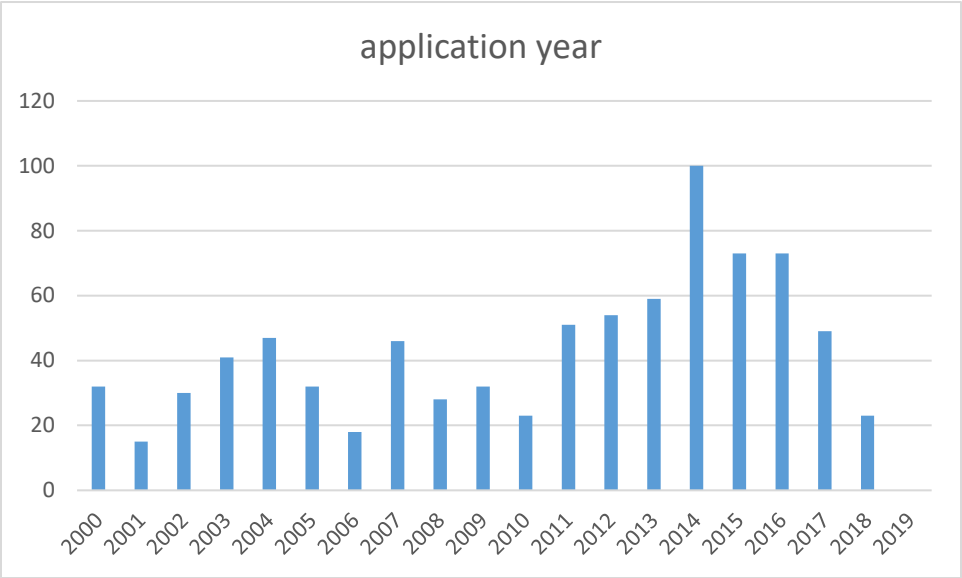


Figure 12 – shows the number of patents per each year B29C

The previous graph shows the percentage of each year patents for the mentioned IPC code. 2014 with 12 percent has the highest number of patents with 100. Furthermore, I combined all the IPC codes and reached one single table and pie chart for the analysis on application years.

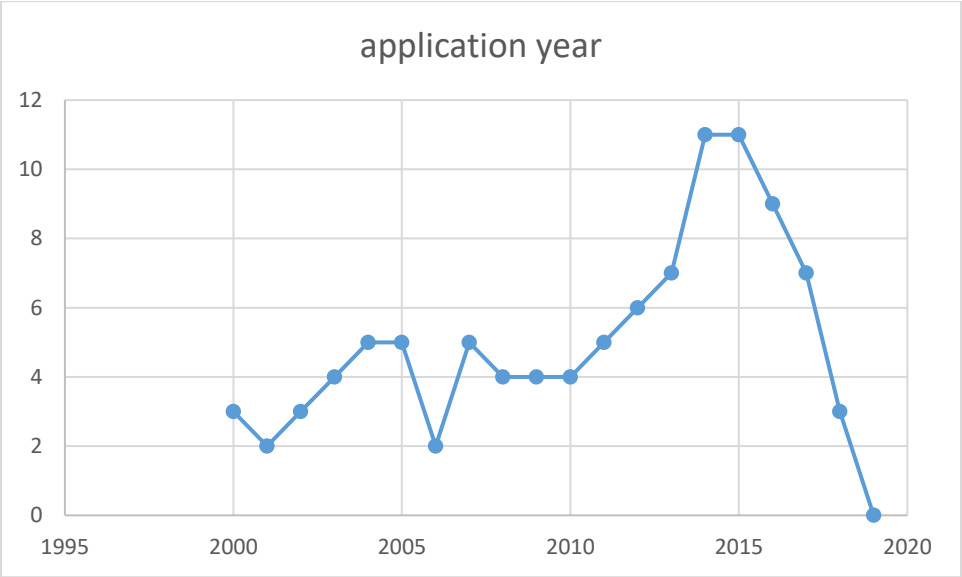


figure 13 – this line graph represents the same data as above however will show how was the trend in 19year application

Meanwhile, the highest number of patents was for 2014 according to the following table and the lowest one was for 2006. It is concluded that in the recent year due to the huge drop in oil prices. companies had to shift to better and more efficient companies and put their effort in developing new systems, which will reduce their cost while at the same time will increase their profit.

Application year	Number of patents	Percentage (%)
2000	38	3.25
2001	26	2.22
2002	34	2.91
2003	47	4.02
2004	60	5.14
2005	58	4.97
2006	21	1.79
2007	57	4.88
2008	45	3.85
2009	51	4.37
2010	42	3.59
2011	63	5.39
2012	66	5.65
2013	79	6.76
2014	132	11.31
2015	125	10.71
2016	109	9.34
2017	76	6.51
2018	38	3.25
2019	0	0
Total	1167	100

Table 8 – shows the percentage as well as patents number for all the selected IPC CODES related to petroleum drilling robotics

This will terminate my analysis in the term of application year for robotics patent in 19years period. However, I did an analysis on petroleum drilling bits and I will represent the data in the following table and graph.

Application year	Number of patents	Percentage(%)
2000	142	2.64
2001	234	4.35
2002	171	3.18
2003	191	3.55
2004	305	5.67
2005	375	6.97
2006	356	6.62
2007	477	8.87
2008	439	8.16
2009	384	7.14
2010	265	4.76
2011	270	5.02
2012	273	5.08
2013	270	5.02
2014	323	6.01
2015	291	5.41
2016	231	4.29
2017	223	4.14

2018	151	2.80
2019	3	0.05
total	5374	100

Table 9 – demonstrates the number and percentage of each patent according to the application year for drilling bit innovations

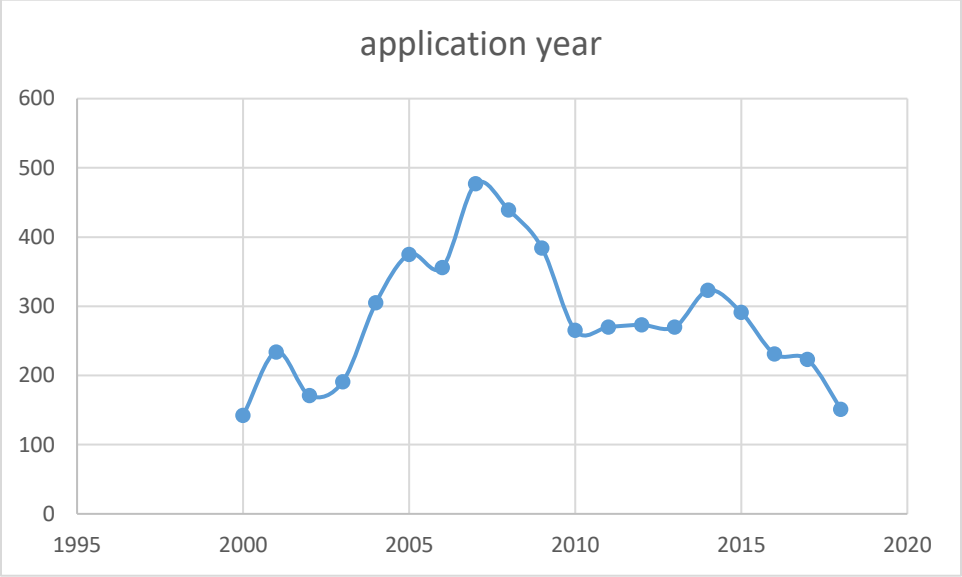


Figure 14 – shows the number of each patent and its total trend for petroleum drilling bits

As can be seen from the graph the peak of patents was the timeframe between 2005 and 2010 and it is decreasing so far in the second decade of this century.

Lastly, by combining both drilling bits and drilling robotics innovation. I reached the following line graph.

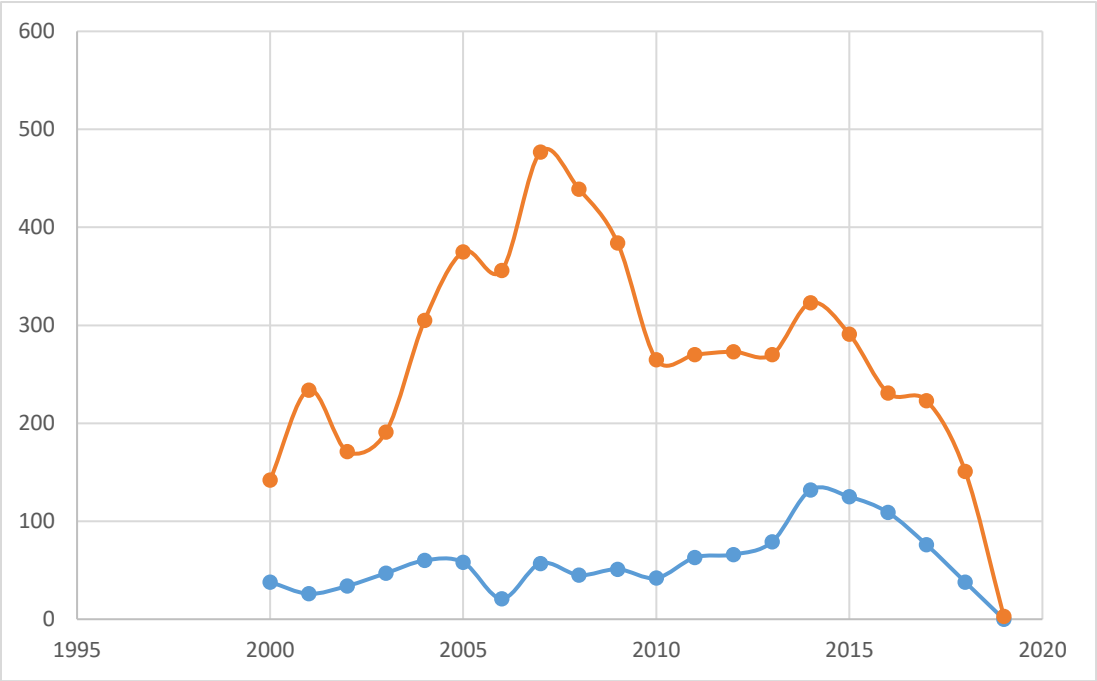


Figure 15 – shows both drilling robotics and drilling bit innovations together. while blue is related to robotics and orange is drilling bits.

The following line graph will show the percentage of both drilling bits and robotics together. The colors are the same as above.

5.2Assignee analysis

In the terms of the companies who are pioneers in petroleum engineering. I did a analysis and I reached interesting results in regards of the manufacturing companies. The majority of patents in petroleum engineering are done mostly by united states and recently china reached or in some cases even passed the united states. European union is third in my list. Meanwhile, Russian companies are developing less compare to their reserves of oil and gas. After all, they have the highest reserve of natural gas, which is way cleaner of petroleum in order to produce energy.

In the case of IPC CODE B28B, companies like HALLIBURTON ENERGY SERVICES INC and J.C STEELE& SONS have the highest patents with 19 and 13 respectively. Meanwhile, SCHLUMBERGER which presumably should have highest number of patents have only 5 patent.

The following table will show the number of patents with regards of their companies.

Assignee company	Number of patents	Percentage(%)
HALLIBURTON ENERGY SERVCES INC	19	18.09
J C STEELE &SONS INC	13	12.38
HARPER TOM	8	7.61
HUTCHINSON DAVID	8	7.61
KIRSPEL LARRY J	7	6.66
STEWART JAMES R	7	6.66
DEROCHE TERRY JR	6	5.71
SCHLUMBERGER TECHNOLOGY CORP	5	4.76
BAKER HUGHES INC	4	3.80
CARBO CERAMICS INC	3	2.85
SANDIVIK INTELLECTUAL PROPERTY	3	2.85
SMITH INTERNATIONAL	3	2.85
OTHERS	19	18.09

Table 10 – demonstrates the top 12 companies and persons with the highest number of patents in IPC CODE B28B

In addition to the companies, there are also individuals who applied for patents in order to preserve their invention.

In the second IPC code (B25J), I did the same analysis and in this case it was different. Frank INR INC has the highest number of patents with 7 and companies like haliburton and schlumbeger are second and third respectively . The following table is the companies with respect of their number of patents.

Assignee	Number of patents	Percentage (%)
FRANK INR INC	7	2.96
KLEIN ELLIOT	7	2.96
ELLUME AS	6	2.54
SCHLUMBERGER TECHNOLOGY CORP	5	2.11
SAUDI ARABIAN OIL CO	5	2.11
NAT OILWELL VARCO NORWAY AS	5	2.11

NAT OILWELL VARCO LP	5	2.11
UNIV JILIN	5	2.11
TOT HOLDINGS INC	4	1.69
BAKER HUGES INC	4	1.69
HALLIBURTON ENERGY SERV INC	4	1.69
UNISTO OY	4	1.69
OTHERS	175	74.15

Table 11 – demonstrates the number and percentage of each patents of IPC CODE B25J

Furthermore, in the case of the third and last IPC code in drilling robotics patent, the following results gained through the excel and in this case company like baker got over schlumberger and hallliburton energy services. Baker with 88 patents surpass schlumberger with 44 and Halliburton with 38 patents.

Assignee	Number	Percentage(%)
BAKER HUGHES A GE CO LLC	88	10.65
SCHLUMBERGER	49	5.93
HALLIBURTON ENERGY SERVICES INC	38	4.60
KUREHA CORP	28	3.38
WEATHERFORD TECH HOLDINGS LC	24	2.90
PRAD RES AND DEV LTD	23	2.78
EVENTURE GLOVAL TECHNOLOGY	22	2.66
IMP COLLEGE INNOVATIONS LTD	19	2.30
MAGMA GLOBAL LTD	15	1.81
J C STEELE SONS INC	14	1.69
HARPER TOM	13	1.57
HEAD PHILIP	13	1.57
OTHERS	480	58.11

TABLE 12 – represents the patent and percentage of patents related to IPC CODE B29C

The highest percentage of patents in robotics related to petroleum drilling engineering is done by BAKER AND HUGES company. The second and third rank is followed by schlumberger and Halliburton. In the case of Chinese companies, there are a lot of institute while the majority have only 1 patent. The highest one was Shandong university with 5 patents.

In the case of drilling bits, I was able to find 1086 assignee for 5379 patents that were found. The majority like other cases were patented by persons instead of company. However, I decided to diminish them to companies with more than 5 patents in possession during the time period from 2000 to 2019. As a result, I was able to find 103 patents.

assignee	number	Percentage(%)
Baker Hughes Incorporated	645	11.99
Halliburton Energy Services Inc	317	5.89
Smith International Inc	289	5.37
SCHLUMBERGER TECHNOLOGY CORP	244	4.53

Oration	222	4.12
Varel International Inc	56	1.04
CANADA LIMITED	48	0.89
Holdings Limited	46	0.85
SANDVIK INTELLECTUAL PROPERTY AB	43	0.79
Camco International (UK) Limited	43	0.79
Technology B.V	40	0.74
SERVICES PETROLIERS	37	0.68
TDY INDUSTRIES INC	37	0.68
BAUER MASCHINEN GMBH	37	0.68
KENNAMETAL INC	35	0.65
HILTI Aktiengesellschaft	31	0.57
OTHERS	3179	59.43

Table 12 – shows the number and percentage of top companies and persons with highest number and percentage in drilling bits innovations.

I was able to find 6 companies who had the highest number of patents in drilling bits and robotics. companies like schlumberger , baker and huges and haliburton had the highest number .

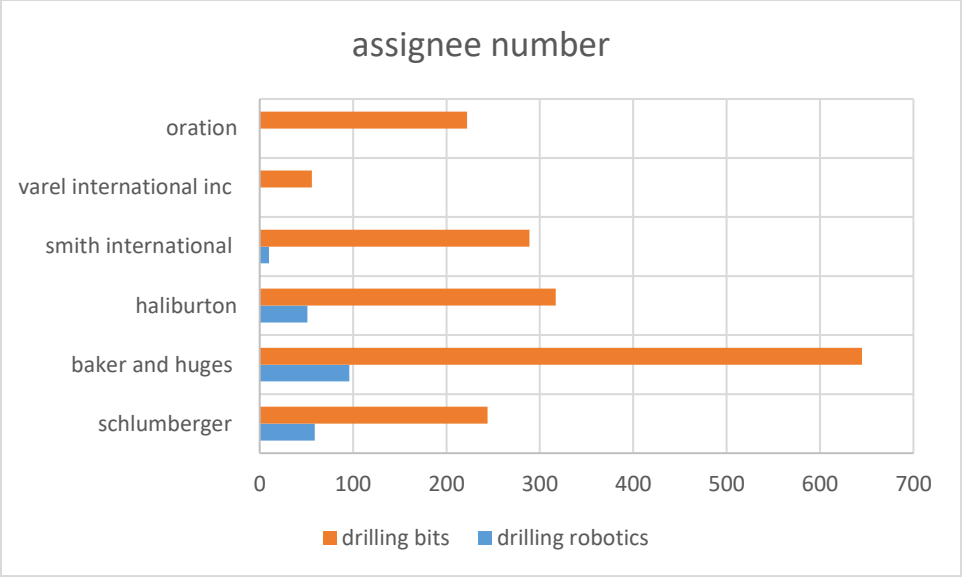


Figure 16 – shows the number of patents in common companies in both drilling bits and robotics

5.3 application country analysis

The next analysis that I did was in the case of application countries. I wanted to know which country is superior in making patents related to petroleum drilling robots.

In The case of first IPC code B28B with 105 patents the following results gained.

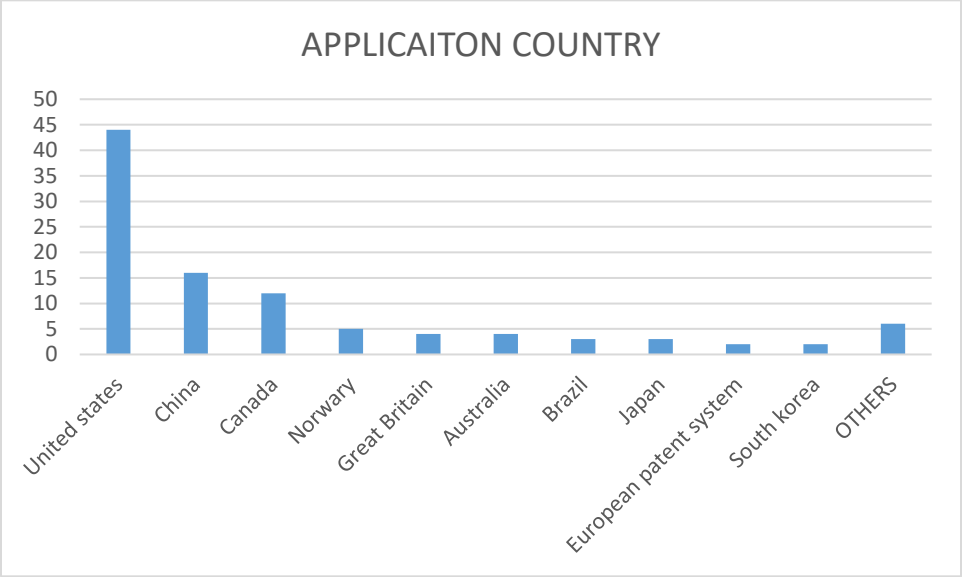


Figure 17 – demonstrate each country share of patents in robotics related to IPC CODE B28B

AS you can see united stated, with a huge gap has the highest number of patents in the world. China is the second one in this table. I will demonstrate also their percentage in the table and a line graph.

Application country	NUMBER	Percentage(%)
United states	44	41.90
China	16	15.23
Canada	12	11.42
Norwary	5	4.76
Great Britain	4	3.80
Australia	4	3.80
Brazil	3	2.85
Japan	3	2.85
European patent system	2	1.90
South korea	2	1.90
OTHERS	6	5.70

Table 13 – shows the number and percentage of patents related to IPC CODE B28B

As can be seen the nearly 42 percent of patents were done by united stated and the second near country is china with 15 percent of patents. Meanwhile, Canada has the third place with 11.42 percent.

In the case of second IPC code B25J, I Reached the following results.

Application country	Patents	Percentage(%)
United states	68	28.81
China	64	27.11
Japan	6	2.54
European patent	23	9.74
Canada	20	8.47
South korea	13	5.50
Australia	7	2.96
Singapore	5	2.11
Great Britain	5	2.11
Norway	5	2.11
OTHERS	18	7.58

Table 14 – represents the number and percentage of each country in the IPC CODE B25J related to drilling robotics

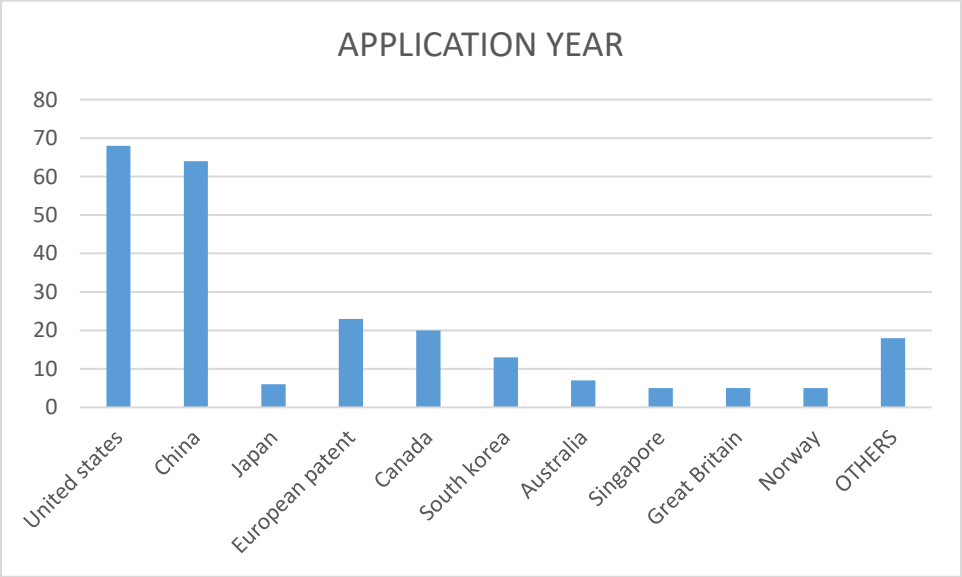


FIGURE 18 - represents the percentage of each country for the IPC CODE B25J

As can be seen from the bar chart the majority country again is the united states and china is following it with slight difference. Meanwhile, European union stays in the third place.

Furthermore, I did the same analysis on the last IPC codes B29C with 826 patents. The following results gained from my analysis.

application country	number	Percentage (%)
united states	289	34.98
China	138	16.70

European patent	85	10.29
Canada	77	9.32
Great Britain	73	8.83
Australia	37	4.47
Brazil	31	3.75
Norway	19	2.30
Japan	14	1.69
France	10	1.21
OTHERS	61	6.24

Table 15 – shows the number and percentage of patents related to each country for the third IPC CODE B29C

The pioneer country again is the united stated followed by its usual rival china.

In the next step, I did an analysis on petroleum patent analysis for all the three patents to realize which country is pioneer in patents relating to petroleum drilling. Overall, the country with the highest number of patents is the united states with 403 patents followed by china with near half difference. Canada and European union are coming third and fourth.

APPLICATION COUNTRY	NUMBER	PERCENTAGE
United states	403	34.59
China	220	19.03
european patent	110	9.51
Canada	110	9.51
great Britain	82	7.09
Australia	48	4.15
Brazil	39	3.37
Norway	29	2.5
Japan	23	1.98
south korea	15	1.29
France	11	0.95
OTHERS	75	6.43

Table 16 – shows the number and percentage of all three IPC CODES combined together

Similarly, the country with the highest percentage of patents is the united stated of America and second rand goes to china with almost half of the US percentage.

Lastly, I will do the same results on drilling bits and will represent my results in the same way.

Application country	Patents	Percentage (%)
China	1381	25.81
united states	1209	22.60
world intellectual property	531	9.92

european patent	367	6.86
Japan	287	5.36
Canada	250	467
south korea	234	4.37
great Britain	227	4.24
Russia	163	3.04
Australia	127	2.37
German	106	1.98
OTHERS	467	8.73

Table 17 – represents the number and percentage of countries related to petroleum drilling bits

In the case of drilling bits percentage, china overtook united states and had the highest percentage with 25 percent.

Meanwhile, I will combine the both petroleum drilling bits and drilling robotics patents and will give two graph representing the results.

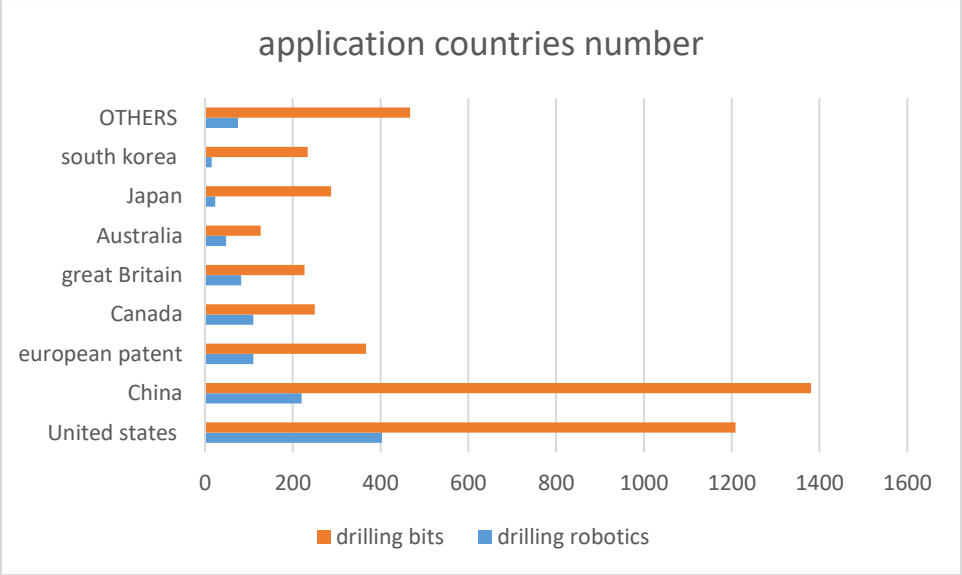


Figure 19 – this figure shows the difference in the number of patents related to drilling bits and drilling robotics in the top common countries for both IPC CODES group

5.4 IPC code analysis

In the last and final analysis, I looked into IPC codes of each patent that I found related to petroleum drilling robotics and drilling bits. I looked for most used patent code for each category that I looked.

Similarly, I will represent my data in three section. Each section related to one IPC code and at the end I will combine them to give final results for petroleum robotics, and will do the same for drilling bits.

In the first case, I will look into the IPC codes that in my first analysis for code B28B.

IPC CODES	number	percentage (%)
B28B000100	17	16.19
B28B000322	15	14.28
B28B001302	16	15.23
E21B003312	14	13.33
B29B000758	14	13.33
B25B002700	14	13.33
B28C000508	14	13.33
B29B000760	14	13.33
B29C003102	14	13.33
B29C004708	14	13.33
B29C004710	14	13.33
B29C004760	14	13.33
B30B000912	14	13.33
B30B001122	14	13.33
B30B001124	14	13.33
B65G003326	14	13.33
E21B001044	14	13.33

Table 18 – shows the top IPC CODES with highest repetition with their percentage

By combing the E21B and B28B, I reached the previous graph. 17 patents contain B28B which is related to petroleum drilling system. Meanwhile, the second IPC code is B28B 13/02 which stands for machines with single working spindle. In addition, the third IPC B28B 3/22 related to Turning-machines or devices with rotary tool heads. Furthermore, there are 13 IPC codes that each have 14 patents related to them. There is IPC Code B28B 7/58 which stands for component parts, details or accessories, auxiliary operations. I will put their definition in a single table by using the WIPO website.

IPC CODE	DEFINITION
B28B000100	PRODUCING SHAPED ARTICLES FROM THE MATERIAL
B28B000322	PRODUCING BY SCREW OR WORM

B28B001302	FEEDING THE UNSHAPED MATERIAL TO MODULS OR APPRATUS FOR PRODUCING SHAPTED ARTICLES
B29B000758	COMPONENT PARTS , DETAILS OR ACCESSORIES , AUXILARY OPERATIONS
B25B002700	HAND TOOLD OR BENCH DEVICES , ESPECIALLY ADAPTED FOR FITTING TOGETHER OR SEPERATING PARTS OR OBJECTS
B28C000508	USING DRIVEN MEHANICAL MEANS AFFECTING THE MIXING
B29B000760	FOR FEEDING E,G, END GUIDES FOR THE INCOMING MATERIAL
B29C003102	DISPENSING FROM VESSELS E,G, HOPPERS
B29C004708	EXTRUSION MOULDING , EXPRESSION THE MOULDING MATERIAL THROUGH A DIE OR NOZZLE
B29C004710	EXTRUSION MOULDING , EXPRESSION THE MOULDING MATERIAL THROUGH A DIE OR NOZZLE
B29C004760	EXTRUSION BY USING SCREWS
B30B000912	PRESES SPECIALLY ADAPTED FOR PARTICULAR PURPOSES USING PRESSING WORMS OR SCREWS CO-OPERATING WITH A PERMEABLE CASING
B30B001122	EXTRUSION PRESSES , DIES THEREFOR
B30B001124	EXTRUSING USING SCREWS OR WORMS
B65G003326	SCREW IR RITART SOURAK CIBVETIYRS
E21B001044	BITS WITH HELICAL CONVEYING PORTION
E21B003312	PLUGS FOR CEMENTING

Table 19 – give the definition of each of the mentioned IPC CODES in table 18.

In addition, I will do the same analysis on the second IPC CODE B25J with 236 patents.

IPC current	number	percentage (%)
E21B001914	54	22.88
B25J000900	36	16.10
E21B001900	27	11.44
E21B001916	26	11.01
B25J000502	24	10.16
B25J000908	22	9.32
B25J001100	20	8.47

B25J000916	20	8.47
E21B001915	19	8.05
B63G000800	19	8.05
E21B004104	18	7.62
E21B001908	16	6.77
B25J001500	16	6.77
B63B003544	15	6.35
E21B000702	14	5.93
B64G000164	13	5.5

Table 20 – gives the top IPC CODES that were repeated in drilling robotics analysis.

In the following table, I will give each code definition.

IPC CODES	DEFINITION
E21B001915	ROCKING OF RODS IN HORIZONTAL POSITION , HANDLING BETWEEN HORIZONTAL AND VERTICAL POSITION
E21B001914	RACKS , RAMPS , TROUGHS ORBINS , FOR HOLDING THE LENGHTS OF ROD SINGLY OR CONNECTED
B25J000900	PROGRAMME CONTROLLED MANIPULATORS
E21B004104	MANIPULATORS FOR UNDERWATER OPERATIONS E.G TEMPORARILY CONNECTED TO WELL HEADS
E21B001916	CONNECTING OR DISCONNECTING PIPE COUPLINGS OR JOINTS
B25J001500	GRIPPING HEADS
B25J001100	MANIPULATORS NOT OTHERWISE PROVIDED FOR
E21B001900	HANDLING RODS , CASINGS,TUBES OR THE LIKE
B25J000502	TRAVELLING ALONG A GUIDEWAY
B25J000916	PROGRAMME CONTROLS TORAL FACTORY CONTROL
B25J000908	PROGRAMME CONTROLLED MANIPULATORS CHARACTERISED BY MODULAR CONSTRUCTIONS
B63B003544	FLOATING BUILDINGS STORES , DRILLING PLATFORS , OR WORKSHOPES
B64G000164	SYSTEMS FOR COUPLING OR SEPARATING COSMONAUTIC VEHICLES OR PARTS THEREOF
E21B001908	APPARSTUS FOR FEEDING THE RODS OR CABLES

E21B000702	SPECIAL METHODS OR APARATUS FOR DRILLING CHARACTERISED

Table 21 – give the definition of each IPC CODE represented in table 20.

The most patents are focused on holding the pipes on drilling rigs with 54 number of patents. It is then followed by connecting and disconnecting of joints on the drilling bits. The full review will be given at the end where I will combine all the lists.

The last IPC CODE in the drilling robotics is B29C and the same analysis was done on this IPC code.

IPC CODES	NUMBER	percentage (%)
E21B003312	176	21.3
E21B001701	91	11.01
E21B001700	82	9.92
E21B001710	70	8.47
B29C004514	68	8.23
B29C004700	66	7.99
F16L001112	52	6.29
E21B004310	51	6.17
E21B001702	46	5.56
B29C004702	43	5.2
B29C006700	42	5.08
E21B001720	40	4.84
B29C003502	40	4.84
E21B001722	39	4.72
E21B000720	36	4.35
F16L000900	34	4.11
E21B004712	31	3.75
B29C006500	31	3.75

Table 22 – shows the top IPC CODES with highest repetition for B29C IPC CODE

Then, I will combine these three codes and give the final results for drilling robotics patents. In this IPC codes, I was able to find 946 IPC codes .. Meanwhile, I will combine all the IPC codes and reach a single graph for all the IPC codes.

IPC CODES	NUMBER	Percentage(%)
E21B003312	190	16.43
E21B001701	91	7.87
E21B001700	82	7.09
E21B001710	70	6.05
B29C004514	68	5.88
B29C004700	66	5.70
E21B001914	54	4.67
F16L001112	52	4.49
E21B004310	51	4.41

E21B001702	46	3.97
B29C004702	43	3.71
B29C006700	42	3.63
E21B001720	40	3.46
B29C003502	40	3.46
E21B001722	39	3.37
E21B000720	36	3.11
B25J000900	36	3.11
F16L000900	34	2.94

Table 23 – shows the top IPC CODES related to petroleum drilling robotics patents with their percentage

The highest IPC code is E21B003312 with 190 patents, the definition of each IPC code will be given in the following table.

IPC CODES	DEFINITION
B29C004700	Extrusion moulding i.e. expressing the moulding material through
B29C004702	With means for avoiding adhesion of the layers
E21B001720	Flexible or articulated drilling pipes
E21B001710	Handling rods , casings , tubes or the like outside the borehole
B29C003502	Heating or curing e.g crosslinking or vulcanizing
E21B003312	Packers , plugs used for cementing
E21B001702	Coupling , joints
E21B001700	Drilling rods or pipes , flexible drill strings , kellies , drill collars
F16L000900	Rigid pipes
E21B001701	Risers
B29C004514	Incorporating performed parts or layers e.g. injection moulding around inserts or for coating articles
B29C006700	Shaping techniques not covered by groups
E21B004310	Setting of casings , screens or liners in wells
E21B001722	Rods or pipes with helical structure
F16L001112	With arrangements for particular purposes e.g. speialy profiled , with protecting layer , heated , electrically conducting
E21B000720	Special methods of earth drilling without removal
B32B001710	Layered products essentially comprising sheet glass of synthethic resin
E21B001914	RACKS , RAMPS , TROUGHS ORBINS , FOR HOLDING THE LENGHTS OF ROD SINGLY OR CONNECTED

B25J000900	PROGRAMME CONTROLLED MANIPULATORS

Table 24 – gives the definition of the IPC CODES that I found has the highest in all the three IPC CODES related to petroleum robotics.

After combining the results of all the three IPC codes. I was able to find 233 IPC codes that have more than 5 patents. The highest one is E21B003312 with 190 patents.

Lastly, I did the same analysis on petroleum drilling bits and then I show the both results on graph. The following table will show the top 18 IPC codes with highest repetition and then I give their meaning.

IPC CODES	NUMBER	percentage (%)
E21B001000	4116	76.94
E21B001042	557	10.41
E21B001043	482	9.01
E21B001060	439	8.20
E21B001056	424	7.92
E21B001062	328	6.13
E21B001046	318	5.94
E21B000700	301	5.62
E21B004400	224	4.18
B22F000706	209	3.90
E21B004100	206	3.85
C04B003552	163	3.04
E21B0010573	162	3.02
E21B001036	150	2.80
E21B001026	149	2.78
E21B001710	148	2.76
E21B001700	143	2.67
E21B001008	138	2.57

Table 25 – shows the number of top IPC CODES related in Drilling bits analysis

The following table will give the definition of IPC codes shown in table 25, those who has the highest number of patents related to them.

IPC CODE	DEFIN ITION
E21B001000	DRILL BITS SPECIALLY ADAPTED FOR DEFLECTING THE DIRECTION OF BORING
E21B001042	ROTARY DRAG TYPE DRILL BITS WITH TEETH
E21B001043	CHARACTERISED BY THE ARRANGEMENT OF TEETH OR OTHER CUTTING ELEMENTS
E21B001026	DRILL BITS WITH LEADING PORTION
E21B001062	DRILLING CHARACTERISED BY PARTS E.G. CUTTING ELEMENTS

E21B001060	DRILL BITS CHARACTERISED BY CONDUITS OR NOZZLES FOR DRILLING FLUIDS
E21B001036	PERCUSSION DRILL BITS CHARACTERISED BY WEAR RESISTING PARTS
E21B001710	WEAR PROTECTORS , CENTRALISING DEVICES
E21B001700	DRILING RODS OR PIPES
E21B001046	DRILLING BITS CHARACTERISED BY WEAR ESISTING PARTS
E21B001008	DRILLING TOOLS ROLLER BITS
E21B004400	AUTOMATIC CONTROL SYSTEMS
E21B004100	EQUIPMENT OR DETAILS NOT COVERED BY GROUPS
E21B000700	SPECIAL METHODS OR APPARATUS FOR DRILLIING
B22F000706	MANUFACTURE O COMPOSITE WORKPIECES OR ARTICLES FROM PARTS
C04B003552	BASED ON CARBON E.G. GRAPHIE
E21B001056	BUTTON TYPE INSERTS
E21B0010573	CHARACTERISED BY SUPPORT DETAILS E.G. THE SUBSTRATE

Table 26 – gives the meaning of IPC CODES that are present in table 25.

Lastly, I will put aside the number and percentage of IPC codes in both petroleum drilling and drilling bits.

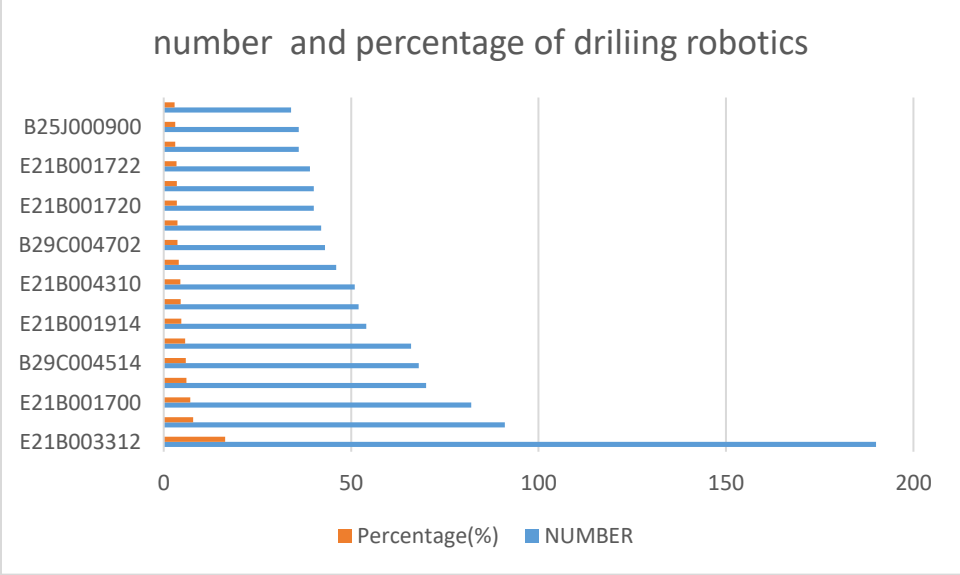


Figure 20 – shows the percentage and number of patents related to drilling robotics patents.

Meanwhile, the same graph was done for drilling bits patents and the result is presented.

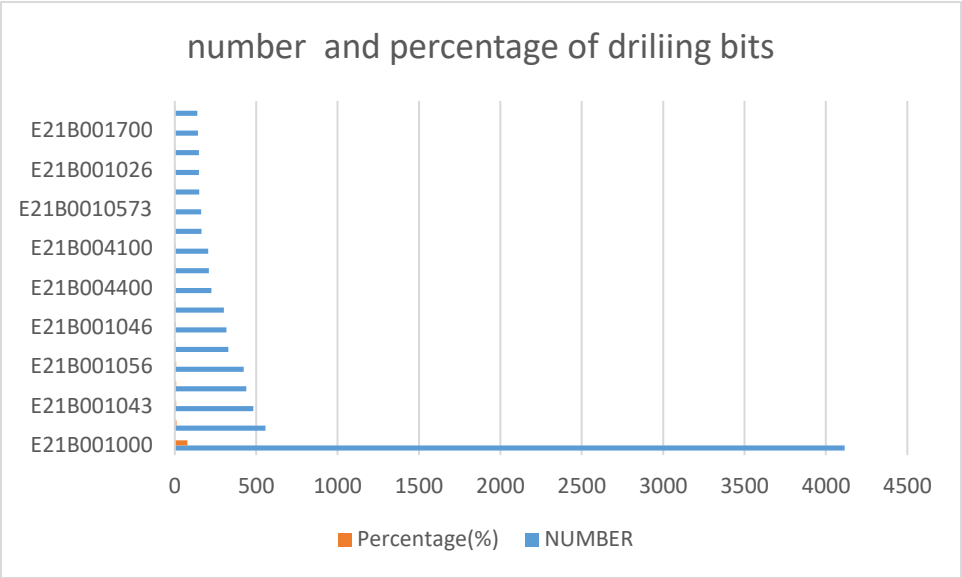


Figure 21 – shows the number and percentage of drilling bits .

This will conclude my analysis, in the following chapter. I will give my conclusion related to each section.

Chapter 6

Conclusion

In terms of application year, for patents related to drilling robotic. The majority of patents was applied in 2014, while the most number of patents for drilling bits was done in 2007. Meanwhile, the least number of patent for robotics was done in 2006 and respective in 2000 for patents in drilling bits. From 2000, the trend for drilling bits shows an upward trend until 2001 when it will reduce however from 2002 the trend is increasing magnificently and reach its top. After that, it reduced and leveled out while there was up and down in the trend. Finally, it reduced dramatically and since 2019 is not finish there is no reliable data related to 2019. Likewise, from 2000, the number of patents increased steadily, while in 2005 it reduced and reached the same amount in 2007. After that it reached a plateau until 2013 when it increased and decreased to 0 in 2019.

Furthermore, in the case of assignee companies. Baker and huges have the highest number of patents in both cases, drilling bits and robotics. It is followed by schlumberger and haliburton . smit international comes fourth in drilling robotics and third in drilling bits. These companies are greatly investing in new technologies in both drilling bits and robotics however the amount of resource they have in their origin county is curbing and it is not like the huge players in oil industry, like Saudi Arabia. However, they changed their focus from building the foundation of drilling to provide more technological services which will bring more prosperity for then while at the same time prevent them from building the oil extraction from scratch.

In terms of application country. After doing all the analysis for all IPC codes. I reached the following results. In the case of drilling robotics, united states of America has the highest number of patents, while it is followed by china and European patent. Meanwhile, in the case of drilling bits. China overtook united states and took the first place while it is nearly followed by its rival united states.

Finally, in the case of IPC codes, I separate all the IPC codes. However, due to the long list of number. I had to summarize them to the highest ones. In drilling robotics, the majority of patents were done in the case of cementing of wells, which seems to be concerning the companies. Cementing is a major operation and it is especially essential since it plays an important role in blow out prevention. A single crack in cement will lead to destabilization of well and the chances of having a blowout is great. It is not so important that BOP cannot prevent this blowout since it comes from outer diameter of well. Another field, which seems to be very interesting, is the fact that robotics related to risers comes in the second place. It is evident that offshore drilling is increasing and companies are looking for new way to decrease their costs especially since they have to pay a huge amount of money for drilling rigs and drilling. riser is essential tool in offshore drilling and developing them will reduce the risk and danger as well as increasing efficiency. As I mentioned earlier. Since the traditional ways of reaching oil is over and companies should look for new supplies of oil, seas play an important role and companies who are having the higher and better technology related to offshore drilling are the major players in the new oil age.

On the other hand, in the case of drilling bits. Companies are investing more in developing bits that have the technology to decrease the well defects as well as preventing their inclination. As we are aware of a small inclination will increase their cost magnificently and in these days that efficiency plays an important role. they must increase theirs. Secondly, it is interesting that companies are investing to increase the harness of their bits teeth which will lower the price, increase the drilling depth.

References

petroleum geology introduction , Dr. Mohammad Rezaie,2015, Iran.

introduction on petroleum geology, Dr. Fereydoon Sabahi, 2009,Iran.

Geology of petroleum (second edition), A.I. LEVERSON, 2004.United states of America

http://www.visions.az/en/news/366/4ca556e3 ,2019)

Foundamentals of petroleum drilling, Dr, Ali zamani, 2014),Iran.

http://www.drillmec.com/en/p/modular-drilling-rigs/

drilling engineering , Alireza moazen , 2013,Iran.

https://www.robotics.org/blog-article.cfm/Robots-in-the-Oil-and-Gas-Industry/40

https://www.britannica.com/topic/World-Intellectual-Property-Organization

https://www.engineering.com/AdvancedManufacturing/ArticleID/11535/Why-Automate-with-Industrial-Robots.aspx

https://www.sciencedirect.com/topics/engineering/patent-system

https://www.theiet.org/publishing/inspec/inspec-content-coverage/international-patent-classification/

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3632996/

https://clarivate.com/products/derwent-innovation/

https://clarivate.com/products/derwent-world-patents-index/

https://www.saudiaramco.com/

http://www.sinopecgroup.com/group/en/

https://corporate.exxonmobil.com/en

http://www.sinopecgroup.com/group/en/business/InternationalOperation2012/

https://new.siemens.com/global/en/company/stories/home.html

https://www.oilandgaseng.com/articles/robots-role-in-the-oil-and-gas-industry/

https://www.bl.uk/business-and-ip-centre/articles/what-is-a-patent

https://emerj.com/ai-sector-overviews/artificial-intelligence-in-oil-and-gas/

https://www.chevron.com/stories/snake-arm-the-robot-who-saves-lives

https://www.sustainableoilfield.com/put-ai-to-work-in-the-oil-gas-industry-meet-watson/

https://blog.linknovate.com/5-oil-and-gas-trends-watch-2018/

https://europa.eu/european-union/topics/development-cooperation_en

https://www.opec.org/opec_web/en/647.htm

https://www.opec.org/opec_web/en/data_graphs/330.htm

https://europa.eu/european-union/topics/energy_en

https://www.oecd-ilibrary.org/energy/natural-gas-information-2018_nat_gas-2018-en;jsessionid=dnwFzNjQKuR6pIVPDd3MQlPI.ip-10-240-5-147

https://data.oecd.org/energy/crude-oil-import-prices.htm

https://www.offshoreenergytoday.com/projects-funded-by-oil-gas-innovation-center-to-generate-500-jobs-by-2023/

https://www.norskpetroleum.no/en/environment-and-technology/petroleum-related-research-and-development/

https://www.norskpetroleum.no/en/environment-and-technology/petroleum-related-research-and-development/

https://www.norskpetroleum.no/en/environment-and-technology/petroleum-related-research-and-development/

https://new.siemens.com/global/en/company/stories/home.html

http://www.oil-gasportal.com/downstream/innovation/

https://www.wipo.int/classifications/ipc/ipcpub/?notion=scheme&version=20190101&symbol=E21B0007300000&menulang=en&lang=en&viewmode=f&fipcpc=no&showdeleted=yes&indexes=no&headings=yes&notes=yes&direction=o2n&initial=A&cwid=none&tree=no&searchmode=smart