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Master of Science Petroleum and Mining Engineering

Abandoned oil and gas wells in sedimentary basins as sustainable sources of geothermal energy

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CHAPTER 1: Introduction to the sedimentary basin as a geological setting that hosted hydrocarbons in the world

1.1 Introduction

Geothermal energy is a renewable energy source derived from the Earth's core. It is generated by heat produced during the planet's formation and the radioactive decay of materials. Using geothermal energy resources has numerous advantages. Geothermal energy is a type of energy that emits less carbon dioxide; it can also be used in a variety of industries and direct applications. Besides, it has a low carbon footprint and is less harmful to the environment than traditional fossil fuel sources.

The Earth's hot reservoirs are naturally replenished, making them both renewable and sustainable. The current global energy consumption is around 15 terawatts, which is far short of the total potential energy available from geothermal sources. While most reservoirs are currently inaccessible, there is hope that with continued industry research and development, the number of exploitable geothermal resources will increase. Geothermal power plants are currently estimated to provide between 0.0035 and 2 terawatts of power (https://www.twi-global.com, 2022). In comparison to other renewable energy sources such as wind and solar power, geothermal provides a consistent source of energy. This is because, unlike wind or solar energy, the resource is always available to be used.

Water temperatures of more than 150°C are required to drive turbines in geothermal power plants (high-enthalpy geothermal resources). In addition, the temperature difference between the surface and a ground source can also be used for direct uses and applications (low-enthalpy geothermal resources). Because the ground is more resistant to seasonal heat changes than the air, the subsoil can act as a heat sink/source of energy. Energy generated by this resource is simple to calculate because it does not fluctuate as much as other energy sources such as solar and wind. This means that we can accurately predict the power output of a geothermal system. Because geothermal energy is a naturally occurring resource, no fuel is required, unlike fossil fuels, which are finite resources that must be mined or extracted from the earth.

There is a lot of scientific research going on in geothermal energy right now, which means that new technologies are being developed to improve the efficiency of the different energy production processes. Besides, an increasing number of projects underway to improve and expand this sector. Many of the current drawbacks of geothermal energy can be mitigated by this rapid technological evolution.

Considering the resources potentially harnessable in oilfields, the energy production based on the exploitation of the available profound geothermal energy associated with disused hydrocarbon wells could also represent a considerable future energy solution. It could solve problems related to suspended oil and gas wells near municipalities, allowing us to hypothesize long-term scenarios for oilfields exploitation. Currently, the use of oil and gas wells for this purpose is more expedient and less expensive, as the cost of investment in wells drilled for geothermal energy is quite high. Before using this type of abandoned wells, the effect of temperature on the rocks and layers in the wells must be taken into account.

Considering the temperature ranges associated with wells in hydrocarbon fields, energy companies and researchers have recently started to work on developing various strategies for using this type of geothermal energy resource. The majority of works that have been carried out on existing abandoned petroleum wells have focused on open-loop systems. An advantageous alternative was found in the use of closed-loop deep geothermal systems (a closed-circuit of pipes).

The thesis aims to discuss the potential and limits of oil and gas fields located in sedimentary basins for geothermal energy extraction, focusing on the technical parameters of wells located in different regions. Well temperature, well construction techniques are considered. Factors such as the application of geothermal energy extraction methods, their impact, suitability for long-term use, economic efficiency were also analysed.

1.2 Sedimentary basins

A sedimentary basin is a section of the Earth's crust covered by a thick series of sedimentary rocks. Hydrocarbons are generally found in sedimentary basins, one of the pillars of the sedimentary organic hypothesis for the genesis of hydrocarbons is this essential reality. As a result, it's critical to pay attention not just to the specifics of traps and reservoir rocks, but also to the larger picture of sedimentary basin studies. Before purchasing land in a new region or seeking to discover drillable prospects, it is vital to determine the type of basin to be appraised, as well as what profitable pathways it may include and where they'd be widely distributed.

A sedimentary basin is a part of the earth's surface where sediments accumulate to a greater depth than nearby areas. There is no clear boundary between the lower measurement limit of the basin and the upper measurement limit of the syncline. Most geologists would consider a reasonable dividing line to be more than 100 kilometers long and more than 10 kilometers wide. The majority of sedimentary basins consist of thousands of square kilometers in size and they can contain more than 5 kilometers of sedimentary fill.

Sediments accumulating on the shelves near the continent's edges generate a variety of geologic formations as a result of the direction and stress put on them by moving crustal plates.

1.3 Divergent continental margins

On the sides of continents moving away from a growing ocean rift, divergent continental margins form. The east coastlines of North and South America, as well as the west coasts of Europe and Africa, were formerly connected at the mid-ocean rift. When evaluating sedimentation and the characteristics of a sedimentary basin, it is necessary to evaluate the entire geographical area that supplied the detrital materials that have accumulated in the basin as sediments, as well as the environmental circumstances of the many sedimentation episodes. Richard Chapman [4], defined this as the physiographic basin, an area undergoing erosion that will furnish material in a depositional basin or depression for the sediments accumulating on the surface of the land or sea floor. The geology of the periphery areas of weathering and erosion, as well as the physiography and climate of the whole interacting area, define the composition of the sediments.

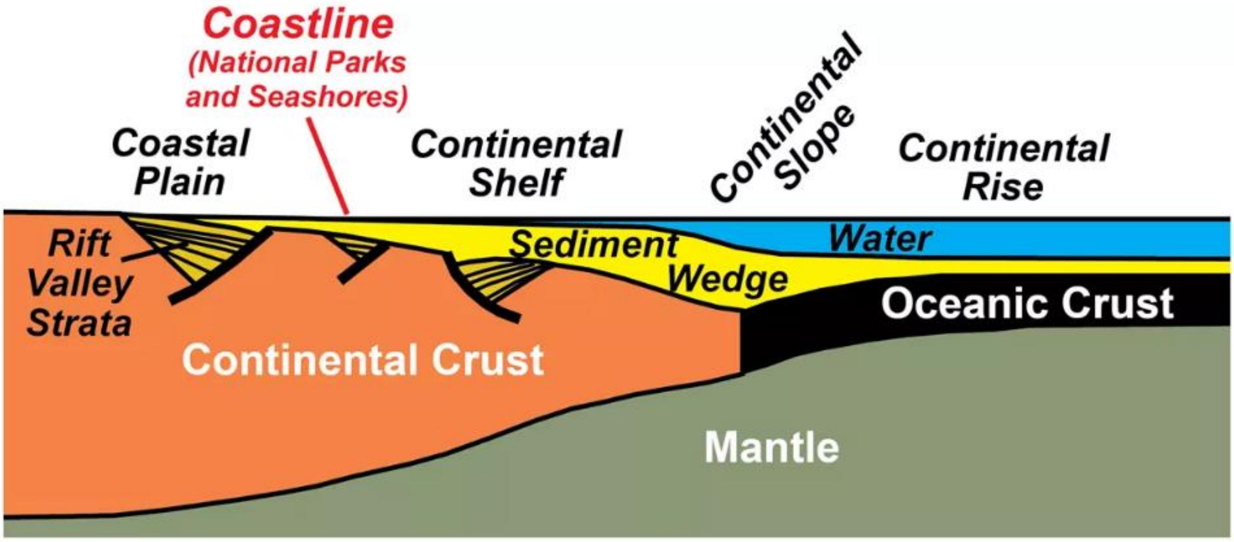


Figure 1. 1. Simplified sketch map of a Passive Continental Margin *(Lillie, 2020)*

1.4 Convergent margins

When two crustal plates contact, convergent continental borders form.

1) Continental-oceanic convergence.

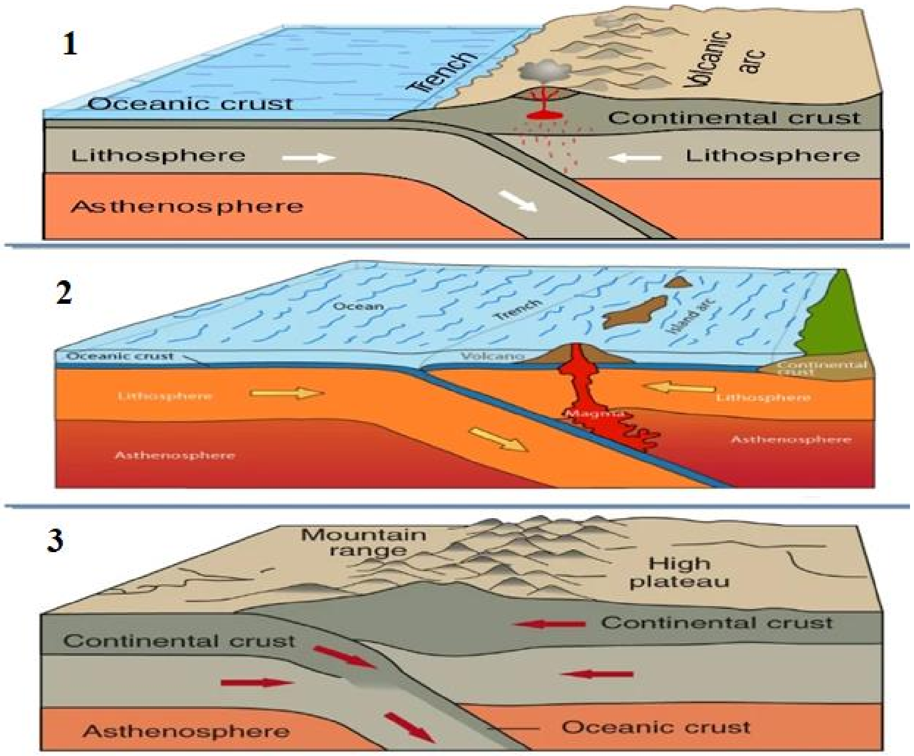
The thick oceanic lithosphere subducts beneath the less dense continental lithosphere when oceanic and continental lithosphere clash. As deep-sea sediments and oceanic crust are scraped off the oceanic plate, an accretionary wedge emerges on the continental crust. Volcanic arcs arise on continental lithosphere owing to partial melting caused by dehydration of the subducting slab's hydrous materials. A marginal basin arises between the island arc and the continent when an ocean plate collides with a less dense continental plate. Carbonate deposits from marine creatures and clastic from the land mass fill this basin, producing enormous regions for hydrocarbon accumulation similar to the oilfields of Southeast Asia.

2) Oceanic-oceanic convergence.

The colder, denser oceanic lithosphere dips beneath the warmer, less dense oceanic lithosphere when two oceanic plates collide. As the slab descends further into the mantle, dehydration of hydrous minerals in the oceanic crust releases water. This water induces partial melting by lowering the melting temperature of rocks in the asthenosphere. Volcanic island arcs will occur when partial melt rises through the asthenosphere and finally reaches the surface.

3) Continental-continental convergence.

Continental and oceanic crust coexist on certain lithospheric plates. As oceanic lithosphere moves beneath continental crust, subduction begins. The linked continental crust is dragged closer to the subduction zone as the oceanic lithosphere subducts to increasing depths. Subduction processes are changed as continental lithosphere reaches the sinking zone, since continental lithosphere is more buoyant and resists subduction beneath continental lithosphere. A tiny amount of continental crust might be subducted until the slab fractures, enabling the oceanic lithosphere to continue subducting, hot asthenosphere to ascend and fill the hole, and the continental lithosphere to rebound. The construction of a long narrow trough (many hundreds of miles long) termed a geosyncline occurs when the plates continue to move against one other. As mountain development (orogeny) and volcanic activity commence, the resultant trough is filled with extensive layers of sediments that may be raised and folded. The Appalachian Mountains in the United States and the Ural Mountains in Russia are examples of convergent continental margins where sediments accumulated and were then uplifted during an orogenic period to form stable mountains that are eroding today and providing sediments to low land areas on both sides of the mountains.



1. Oceanic – Continental crust; **2.** Oceanic – Oceanic crust; **3.** Continental-Continental crust

Figure 1. 2. Convergent plates *(MissSt, 2015)*

1.5 Formation of a sedimentary basin

Deposition of eroded material and precipitation of chemicals and organic detritus within the aqueous environment build sedimentary basins over hundreds of millions of years.

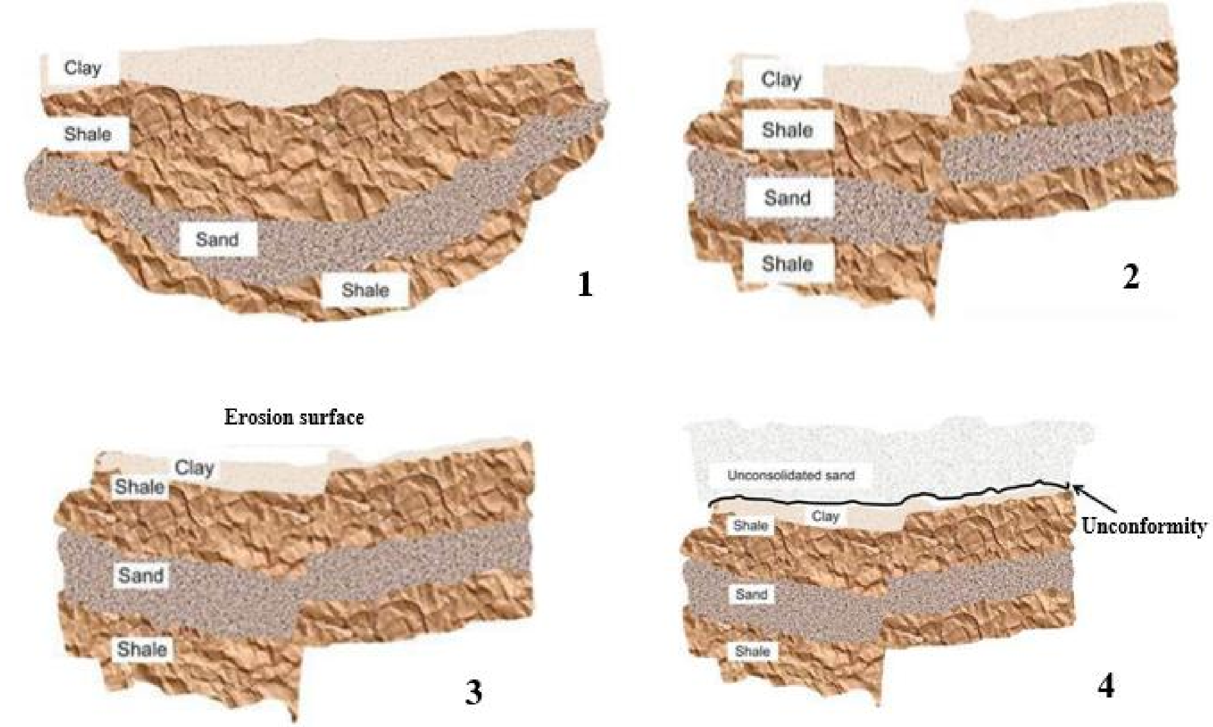


Figure 1. 3. Formation process of sedimentary basin *(Onajite, 2014)*

In the aqueous environment, sedimentation develops over time, and the added weight causes subsidence. Organic substances and various materials deposited at various times over thousands of years will result in regular strata 'layering' in the basin. Faults arise in the basin due to volcanic activity or the movement of the earth's crust. The imagined form of fault creation is shown in **2** of Figure 1.3. Erosion of the high land sections and subsequent subsidence eventually results in the formation of another low-lying area.

Erosion of the high land sections and subsequent subsidence eventually result in the formation of another low-lying area. The water subsequently fills the low-lying terrain, creating a new water habitat. The underlying strata then undergo further sedimentation, resulting in an 'unconformity.' Unconformities are non-depositional surfaces that divide younger strata from older rocks, indicating a break in the geological record. The layers under and above the unconformity may or may not be parallel. Finally, folding and distortion are caused by land mass movement. This results in the construction of thick sedimentary basins complicated formations (Figure 1.4).

A stratum is a sedimentary layer (sand or shale) with a distinct shift in lithology or a physical break in the sedimentation at its top and bottom. The plural of stratum is strata.

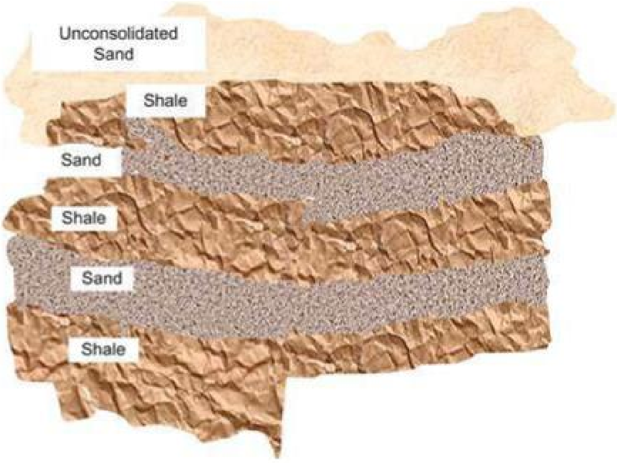


Figure 1. 4. Conceptualized sedimentary basin formation *(Onajite, 2014)*

1.6 Accumulation of sediments

The balance between the energy of the environment and the inertia of the sedimentary particles is required for sediment accumulation in a particular region. Sediments delivered to a river's mouth, for example, may be carried away by waves and currents to a site where the ambient energy is insufficient to move the particles. The notion of base-level is this [4]. Sediments of a certain size and density will collect in an area with the same amount of energy as their base level, while finer grades of the material will be moved in suspension to an area with less energy than their base level. This is the procedure that results in sorting and the accumulation of information. The balance between the energy of the environment and the inertia of the sedimentary particles is required for sediment accumulation in a particular region. Sediments delivered to a river's mouth, for example, may be carried away by waves and currents to a site where the ambient energy is insufficient to move the particles. The notion of basic level [4] is this. Sediments of a certain size and density will collect in a region where the energy level is at its lowest. Finer grades of the material, on the other hand, are unable to accumulate in that site and are moved in suspension to a lower-energy area corresponding to their base level. One section has sand grains, while another contains silt and clay. The base level of a certain area changes throughout time. Thus, sand particles are deposited during one phase of accumulation, and subsequently finer particles of silt and clay are formed on top of the sand. This phase can be repeated several times, resulting in alternate sand and shale deposition and the creation of sand-shale sequences. In flat plains flanked by shallow oceans during periods of low orogenic activity. As a result, erosion of the landmass is minimal, whereas chemical weathering is fast. Because interstitial fluids have a relatively lengthy residence period at or near the surface.

Weathering processes are completed under these circumstances, providing stable components for clastic deposits such as quartz and zircon from igneous and metamorphic rocks. These elements are dragged into the sea's depression and deposited as clean, well-sorted sediments of homogeneous content and texture. The sediments may remain unconsolidated sand formations, or the grains may be cemented by carbonate and silica compounds precipitated from the sea, or by interstitial fluids seeping slowly through the deposits at a later time.

1.7 Oil and gas formations

Sedimentary basins may be found on the borders of continental shelves all over the world. Hydrocarbons resources are formed from sedimentary basin source rock. When enormous amounts of organic (plants and animals) detritus are constantly buried in deltaic, lake, and ocean environments, oil and gas can be produced. In the sinking sedimentary basin, this organic detritus is quickly buried. Sediments containing biological material go deeper into the soil as sedimentation continues and overburden pressure rises owing to increased weight. Organic trash decays typically in the presence of oxygen, but as you go deeper into the sediment, the oxygen-free environment safeguards the organic matter. Rather than being killed by microbes, the organic waste might accumulate. As the earth's temperature rises, sediments and the organic waste they contain heat up as they are buried beneath younger sediments.

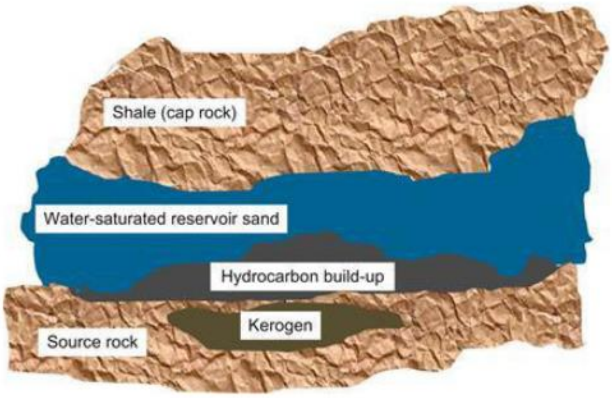


Figure 1. 5. Formation of the kerogen *(Onajite, 2014)*

Kerogen formation process is extremely important in geology since it is the material that produces oil, gas, and coal. What organic material is decaying and the temperature and pressure it has been exposed to over thousands of years determine which of these products is created. The process of hydrocarbon formation appears to be relatively sluggish at temperatures below 150 F, and it reaches its maximum at temperatures between 225 and 350 F. As the temperature of the source rock rises, hydrogen and carbon atom chains break apart and generate heavy oil.

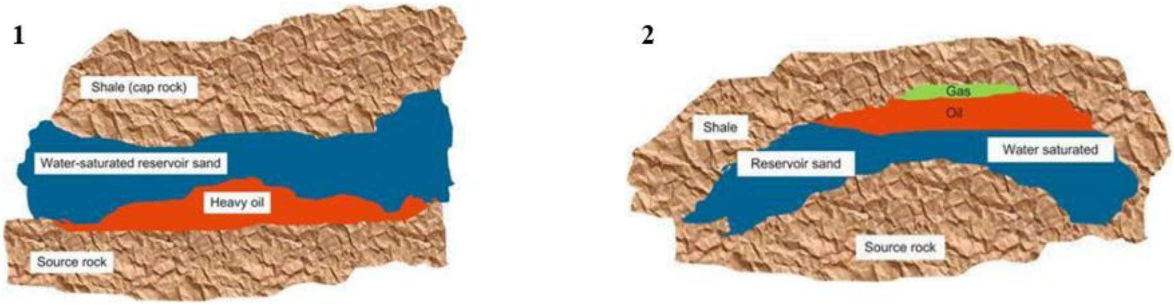


Figure 1. 6. Formation of heavy oil and picture of oil and gas reservoir *(Onajite, 2014)*

The heavy hydrocarbon is transformed to lighter light oil or gas as the temperature rises. Gas can also be produced directly from the breakdown of kerogen in plant wood. A description of this process is shown in the picture **2** in Figure 1.6.

The hydrocarbon generated in the source rocks migrates into the pores of the permeable rocks. Because these hydrocarbons are lighter than the water in permeable rock, they migrate, or travel up through it, until they are stopped by an impermeable rock like shale, where they agglomerate

into bigger quantities. There is now a pocket of oil or gas. The hydrocarbon generated might become a valuable oil and gas field, depending on the size of the reservoir.
The 'oil window,' or the depth range across which oil generation takes place, is distinct for most sedimentary basins. Pool, field, and province are the three types of commercial hydrocarbon deposits.

A pool is the most basic unit of commercial hydrocarbon occurrence in the subsurface. It is a gathering of oil/gas within a single trap in the same reservoir under the same pressure and temperature system. An oil and gas field is a group of hydrocarbon pools that are structurally or stratigraphically associated to the same geologic structure. *(Onajite, Oil and Gas Formation, 2014)*

A province is made up of geological zones with multiple oil and gas resources. Reservoir is a porous and permeable subterranean volume of rock with both storage capacity and the ability to enable fluids to flow through it. Finally, at temperatures above 500 F, the kerogen becomes Carbonised, and hydrocarbons are no longer formed. *(Onajite, Oil and Gas Formation, 2014)*

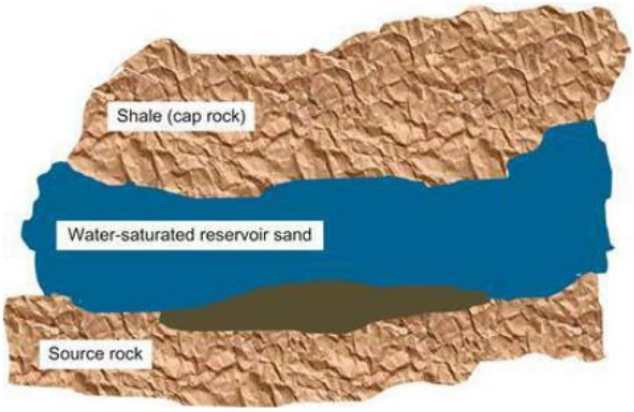


Figure 1. 7. Carbonization of kerogen *(Onajite, 2014)*

1.8 Oil and gas traps

In a sedimentary basin, several formations are generated by the movement of the Earth's crust. As a result, oil and gas can be found in various oil and gas traps. The different sorts of traps are shown below.

Structural Trap

A structural trap is a geologic trap that arises as the subsurface structure changes owing to tectonic, diapiric, gravitational, and compactional forces. These alterations obstruct hydrocarbon movement upwards and can result in the establishment of a hydrocarbon reservoir. The fault trap, anticline trap, and salt dome trap are the three most common structural traps.

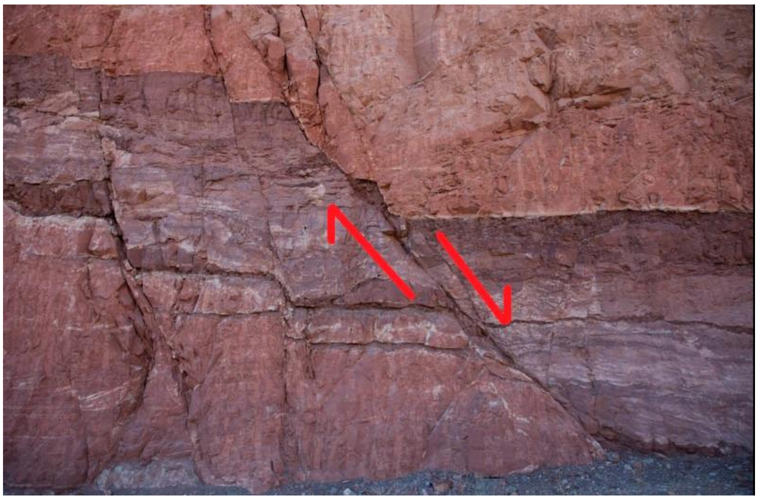


Figure 1. 8. Normal fault (UTAH, USA) *(Segwiki, 2017)*

- Normal fault

A normal fault or gravity fault occurs when the hanging wall slides down in the direction of the fault plane's dip. Because normal faults are syn-depositional and dip towards the sinking basin, they constitute a genetic aspect of the basin formation process. Hydrocarbons can be trapped by a normal fault, which is formed by a fault plane and an impermeable layer on top of the reservoir (Figure 1.8).

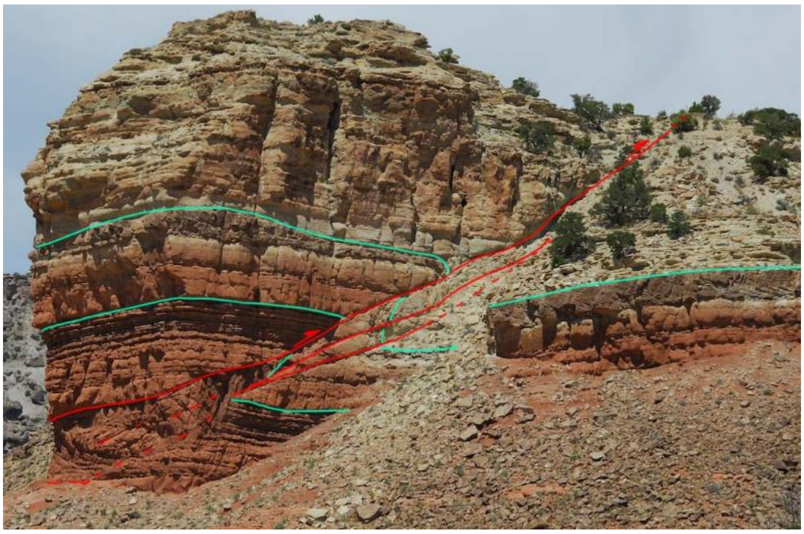


Figure 1. 9. Reverse fault (Ketobe Knob, UTAH) *(Fossen, 2013)*

- Reverse Fault

A reverse fault occurs when the hanging wall slides up along the dip direction relative to the foot wall (Figure 1.9).

- Anticline Trap

A structural trap produced by the folding of rock strata into an arch-like structure is known as an anticline. An anticlinal trap's rock strata were initially laid out horizontally, but earth movement forced them to fold into an arch-like form known as an anticline. This sort of structure is apparent on a seismic section, but because seismic sections are often 'time sections', velocity variations above the anticline may disguise the real structure. The structural outlines of an anticline form closed loops.

An anticline's reservoir rock layer must be covered with fine-grained cap rock, which seals the top and sides. The height of the crest above the lowest structural contour that is closed determines the closure of the anticline trap. The section or depth of the anticlinal structure that may store or contain hydrocarbon is so defined. If the contour below does not shut any hydrocarbon below it, the hydrocarbon will leak into the following structure. Oil or gas is generally used to fill the building. If there isn't enough gas to completely saturate the oil, the extra gas will sit on top of it. The basic gas–oil–water arrangement observed in most anticline traps and other hydrocarbon traps is the result of this.

- The Salt Dome

A salt dome is a trap formed by the intrusion of ductile non-porous salt into stratified rock strata from below. Hydrocarbon can be discovered on the margins of a salt dome as well as in the distorted strata above it.

When the lithology, character of the strata, or depositional pattern change, stratigraphic traps occur. They stop hydrocarbons from migrating across reservoir beds. A sand body formed by river sand might stretch out laterally into an area where clays were deposited in wetlands. The sand body may serve as a reservoir, while the shale serves as a seal (cap rock). On a seismic section, the stratigraphic trap is the most difficult to locate.

So far, we've looked at how sedimentary basins are produced, as well as how oil and gas are generated and trapped underneath. Exploration geophysicists must be able to see through the earth's strata to discover where oil and gas are trapped. Geophysicists use seismic reflection technology to detect oil and gas traps in the subsurface in order to do this.

Stratigraphic Traps

The deposition that occurs in sedimentary rocks is what leads to the formation of these traps. The seals are formed when the sediment that is responsible for creating the rock of the reservoir is deposited in an uneven layer. These seals can be found both on top of and next to the reservoir. These seals are often made of shale that is either impermeable or has a low permeability and is deposited around the reservoir to prevent oil and gas from entering the reservoir. Figure 1.10 shows a stratiographic trap in the bottom righthand corner of the diagram. These kinds of traps can be discovered in clinoforms, in pinching-out sedimentary structures, beneath unconformities, or in structures that were formed by the creep of evaporites.

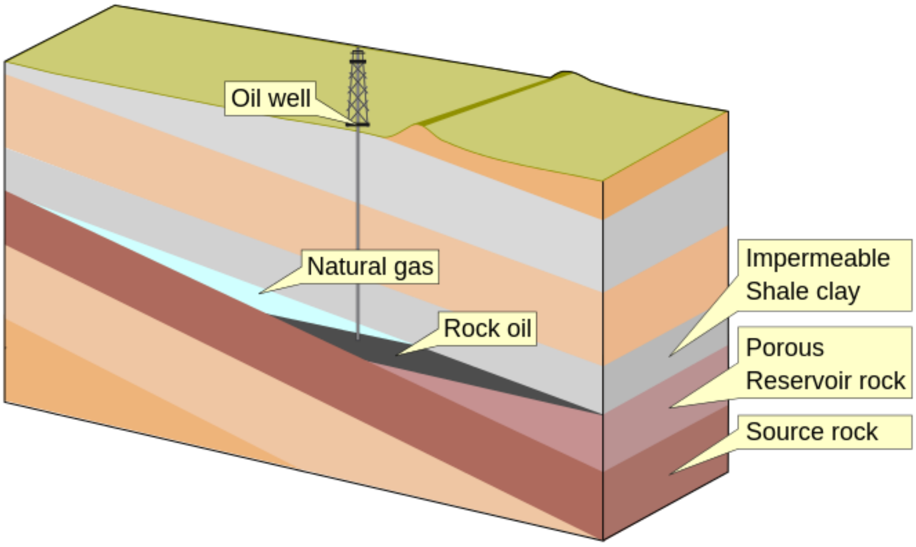


Figure 1. 10. Stratigraphic trap *(Jordan Hanania, 2016)*

The timing of when changes take place in relation to the sedimentation process can be used to differentiate between the two primary types of stratigraphic traps. The changes that take place throughout the sedimentation process are what give rise to the primary stratigraphic traps. In most cases, these are structural changes that come about as a consequence of the discontinuous deposition of sediment. Changes that take place after sedimentation have taken place can result in the formation of secondary stratigraphic traps. Changes in the porosity of the rock can occur as a result of these changes, which can result in the formation of a cap-like rock.

CHAPTER 2: Analysis of the production and consumption of hydrocarbons (oli and Gas) in the World.

Petroleum is not equally distributed around the planet. The Middle East contains slightly less than half of the world's proven reserves (including Iran but not North Africa). Following the Middle East are Canada and the United States, Latin America, Africa, and the former Soviet Union area, which includes Russia, Kazakhstan, and other nations. The amount of oil and natural gas produced by an area is not always proportional to its confirmed reserves. The Middle East, for example, has around 50% of the world's known reserves but only contributes for about 30% of global oil output (though this figure is still higher than in any other region).

There are two overarching concepts that govern global petroleum production. To begin with, the majority of petroleum is concentrated in a few huge fields, although the majority of fields are tiny. Second, as exploration continues, the average size of discovered fields shrinks, as does the amount of petroleum discovered per unit of exploratory drilling. The huge fields are generally discovered first in any location.

Over 50,000 oil fields have been found since the first oil well was drilled in 1848. The influence of more than 90% of these fields on global oil output is negligible. Supergiants, which have 1 billion or more barrels of eventually recoverable oil, and giants, which have 500 million to 5 billion barrels of ultimately recoverable oil, are the two biggest types of fields. These fields contain 14 to 16 percent of all known oil on the planet. Approximately 95 percent of the world's known oil was formerly held in less than 5% of the recognized fields.

2.1 Geologic study and exploration

Early in the exploration cycle, current geologic understanding can typically discriminate between geologically favourable and unfavourable circumstances for oil accumulation. As a result, only a few exploratory wells may be required to determine if a region is likely to have large oil reserves. Petroleum exploration is now a very efficient procedure. If huge fields exist, the first 50 to 250 exploration wells are expected to find the majority of the oil in a region. If there are many more important possibilities than typical, or if exploration drilling patterns are determined by political or exceptional technological concerns, this number may be exceeded. While there may be undiscovered commercial oil resources in any of the 240 studied but seemingly barren basins, they are unlikely to be of considerable significance because the largest fields are usually identified early in the exploring process.

The other 200 basins have had little or no exploration, although enough geologic investigation has been done to determine their size, volume and kind of sediments, and overall structural character.

The majority of underexplored (or frontier) basins are found in challenging conditions, such as arctic areas, beneath salt layers, or along submerged continental borders. The biggest sedimentary basins, those with more than 833,000 cubic kilometers (200,000 cubic miles) of deposits, account for over 70% of known world petroleum. Smaller basins, as well as the more expensive and challenging border basins, will have to be explored in the future.

2.2 Oil reserves

According to the latest estimates *(BP, Statistical Review of World Energy, 2021)*, the Middle East has the largest share of the world's oil reserves at 835.9 thousand barrels. As a region, South and Central America is the second largest zone with oil reserves. Venezuela has 303,800 barrels of reserves and is the world's largest oil producer. According to this figure, it means having 17.5% of oil reserves. If we look at the general trend, we can see that it is focusing on large hydrocarbon reserves. Thus, the oil reserves of countries such as Canada, the United States and Russia depend on general restrictions.

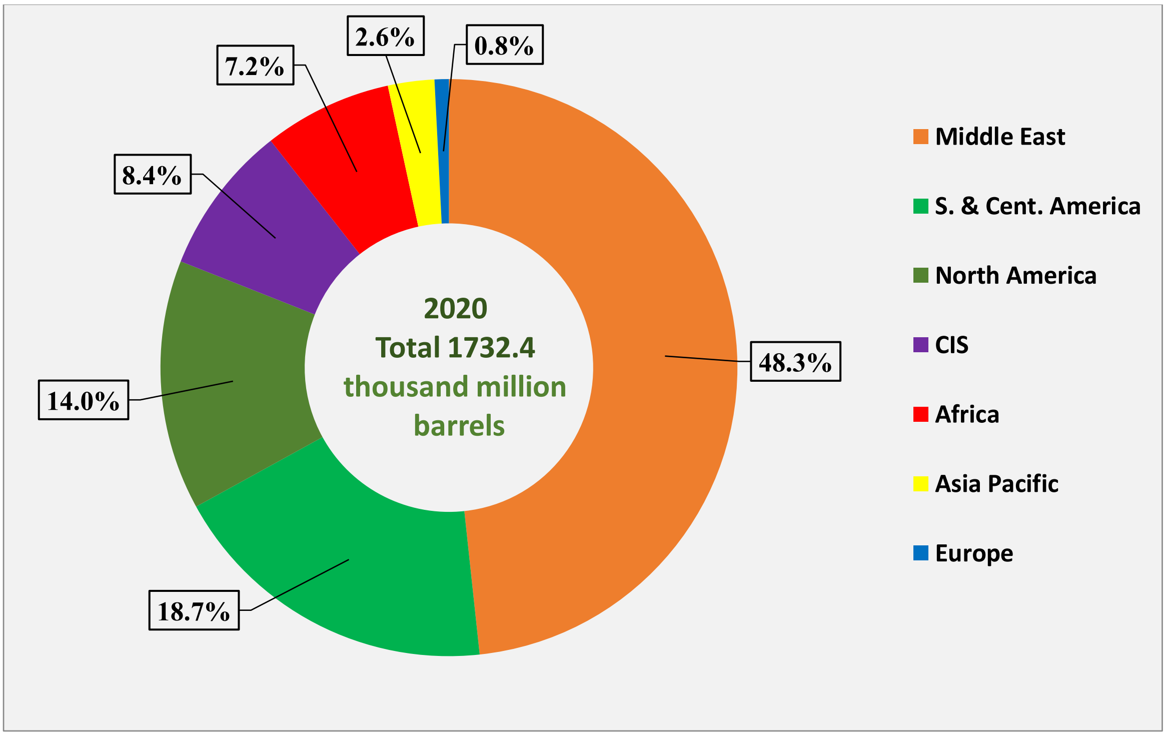


Figure 2. 1. Distribution of oil reserves in the world *(BP, 2021)*

2.3 Oil production

According to known historical statistics *(BP, Statistical Review of World Energy, 2021)*, total global yearly crude oil production peaked at just 300 t in 1857, which is about similar to the daily output of today's high-productivity wells. In 1900, worldwide yearly production was still barely 2043 t after nearly a half-century. Oil output was only 29,000 t per year even before WWII. However, the oil business grew swiftly, fueled mostly by large-scale postwar industrialisation in the United States, Europe, Russia, and Japan. In 2008, annual production reached 3.64 billion t. As a result, supply and demand mismatches faded away, giving way to market circumstances typified by tight equilibrium between the two market forces. The majority of oil is currently produced in six countries and regions: 1.1 billion tonnes in the Middle East, 488 million tonnes in Russia, 256 million tonnes in the United States, 190 million tonnes in China, 140 million tonnes in Mexico, 178 million tonnes in Norway and the United Kingdom combined.

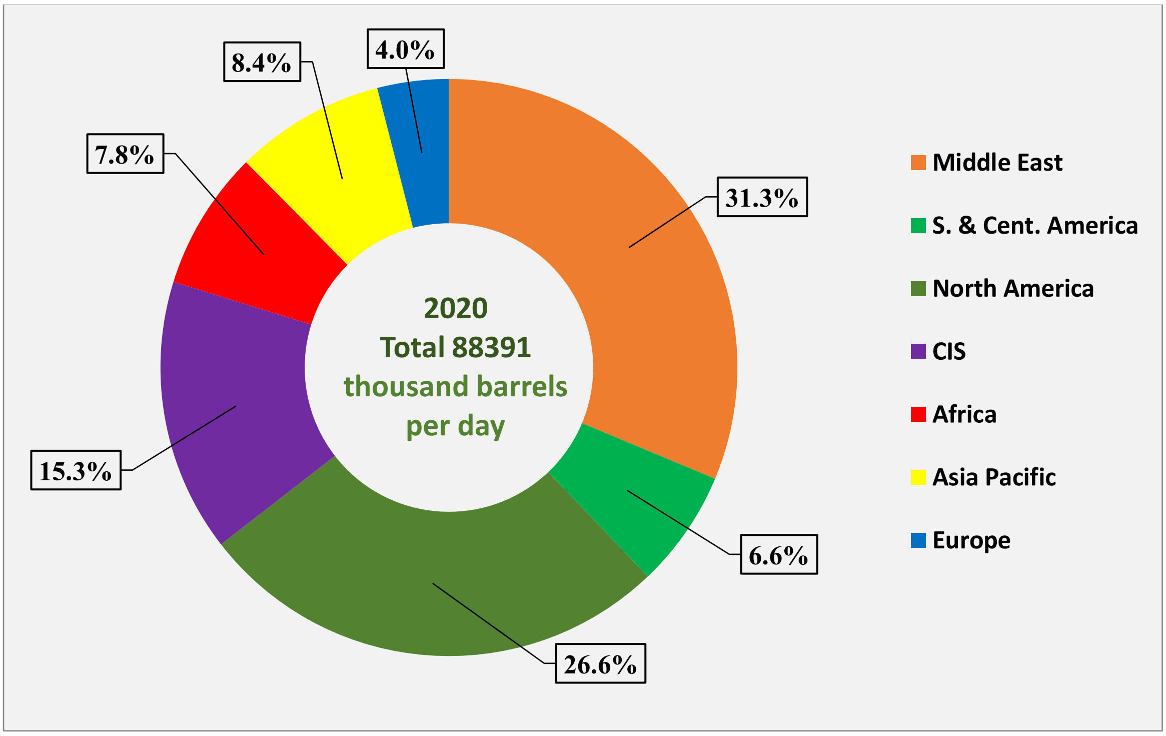


Figure 2. 2. Distribution of daily production of oil in the world *(BP, 2021)*

2.4 Oil consumption

Oil consumption increased by 0.9 million barrels per day (b/d), or 0.9 percent less than the 10-year average of 1.3 percent per year. China's consumption increased by 680,000 barrels per day, the highest rise in the country's demand since 2015. The only notable exception was Iran (180,000 b/d) in the developing world, where growth was below average. Demand in the OECD decreased by 290,000 barrels per day, the first drop since 2014. Ethane and LPG (380,000 b/d) led consumption increase, aided by the substitution of naphtha in petrochemicals, with naphtha demand down marginally (-15,000 b/d). Marine diesel consumption increased slightly above normal (360,000 b/d) as the International Maritime Organization's bunker fuel sulphur standard adjustment in 2020 boosted demand. This adjustment, on the other hand, lowered demand for highsulfur fuel oil, resulting in a 320,000 b/d drop in fuel oil consumption. In 2019, oil production declined by 60,000 b/d as robust non-OPEC production growth, driven by the United States, was countered by a steep drop in OPEC output.

For the third year in a row, the United States saw its output rise by a staggering 1.7 million barrels per day, but this was down from the record growth of 2.2 million barrels per day in 2018. Brazil (200,000 b/d) and Canada (150,000 b/d) both had strong increase, however the latter experienced a major slowdown in comparison to 2017 and 2018.

OPEC output plummeted by 2 million barrels per day, the most since 2009. Iran (-1.3 million b/d) and Venezuela (-560,000 b/d) also saw significant declines due to a combination of sanctions and economic challenges. A renewed OPEC+ production cut deal also decreased output levels in other nations, with Saudi Arabia's production decreasing (430,000 b/d). Despite the deal, certain OPEC countries raised output, particularly Iraq and Nigeria, which increased production by 150,000 and 100,000 barrels per day, respectively.

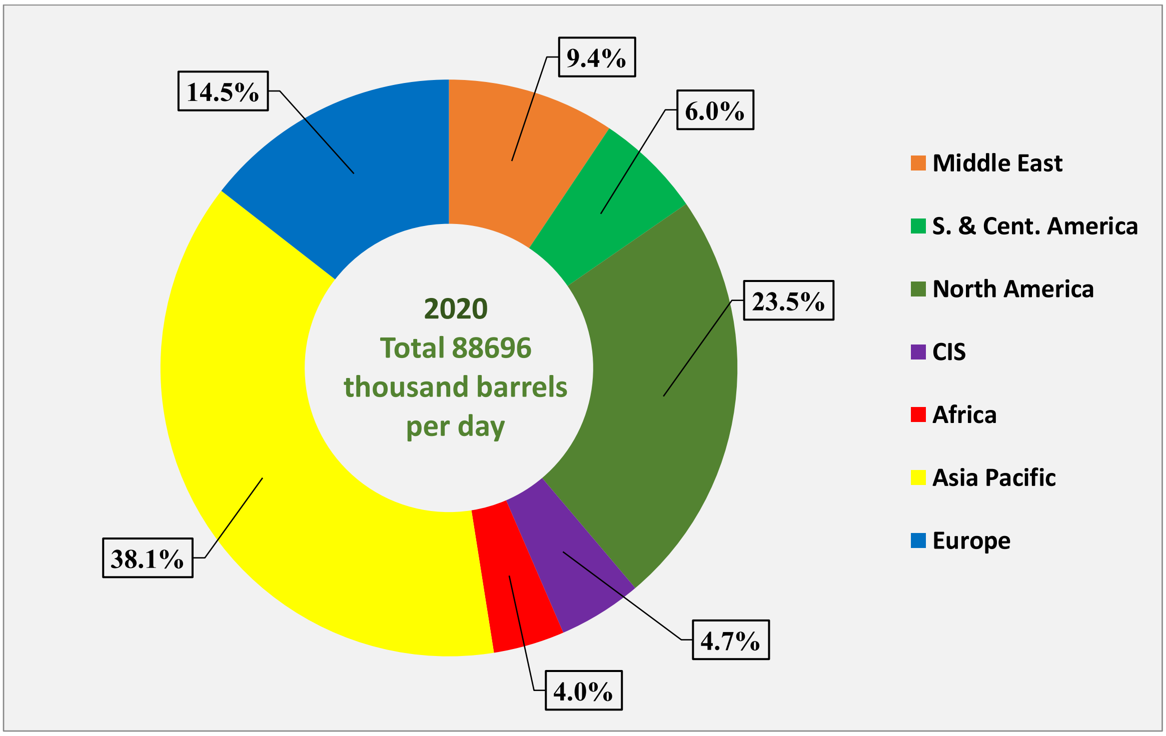


Figure 2. 3. Distribution of daily consumption of oil around the world *(BP, 2021)*

When looking at oil output by type, the biggest drops were in crude oil and condensate, which decreased by 580,000 b/d combined. Natural gas liquids (NGLs) increased by 520,000 barrels per day (4.5 percent) in keeping with their long-term trend. NGL output increase has been predominantly driven by the United States (440,000 b/d), which has quadrupled its production to 4.8 million b/d between 2012 and 2019. Last year, oil prices fell somewhat, with Dated Brent averaging $64.21/bbl, down from $71.31/bbl in 2018. Global oil output is predicted to have dropped by 6.6 million barrels per day (MB/d) in 2020, the greatest drop in postwar history. It's important to divide the year into three stages to obtain a sense of the timing and nature of that supply response.

2.5 Natural gas reserves

The natural gas industry's early disregard was reversed when new gas reserves were discovered (particularly in Russia, Iran, Qatar, Algeria, Saudi Arabia, and Nigeria). This was accompanied by tremendous progress in the technique of liquefying natural gas (LNG) for maritime transport over long distances in specialised LNG ships. Furthermore, gas usage alternatives were swiftly commercialized, resulting in increased demand for gas in the production of petrochemicals, fertilizer, and feedstock, as well as mega-electric power plants.

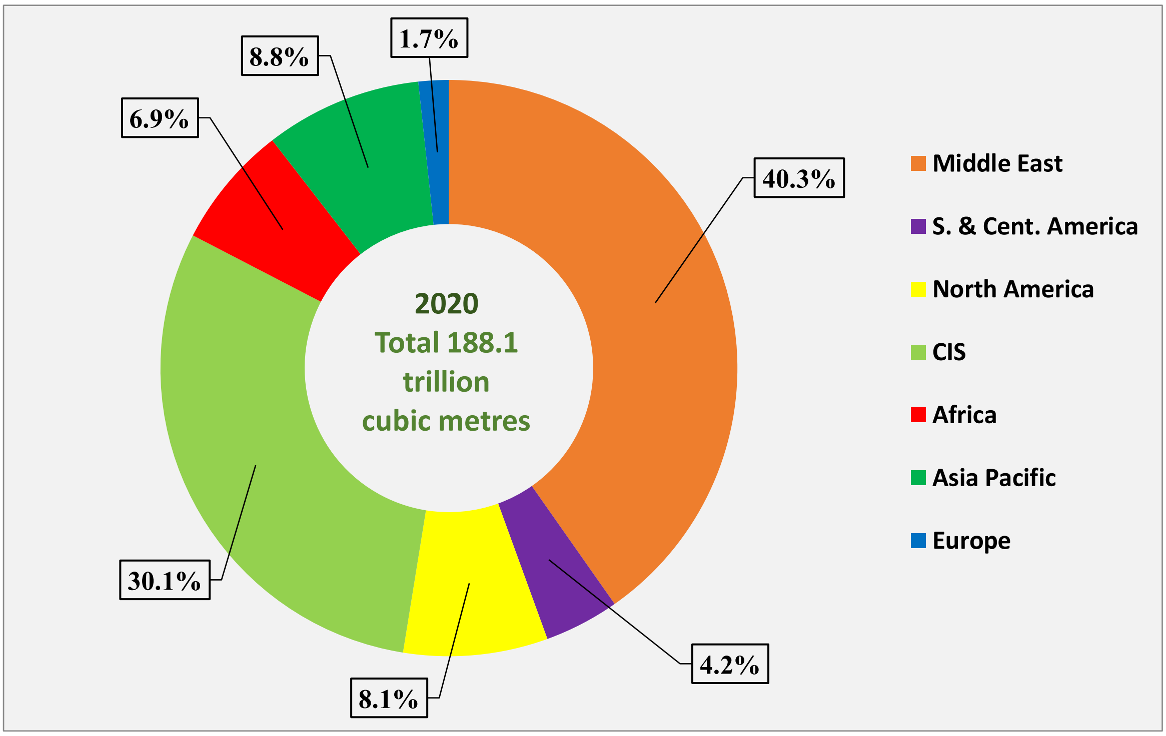


Figure 2. 4. Distribution of gas reserves in the world *(BP, 2021)*

In 1961, recoverable gas reserves were just 19.7 trillion cubic meters, but by 2020, they had risen to 188 trillion cubic meters. At the moment, known gas reserves are focused mostly in three areas. The Middle East has about 76 trillion cubic meters, Russia has 64 trillion cubic meters, and the United States has more over 91 trillion cubic meters.

2.6 Production of natural gas

Gas production figures were compiled considerably later than oil production numbers. Global oil output was 245 million tonnes in 1936, while gas production was 71 billion cubic metres. In 1970, 1988, 2000, and 2004, global gas output surpassed 1 trillion cubic meters, 2 trillion cubic meters, 2.38 trillion cubic meters, and 2.6 trillion cubic meters, respectively. Currently, the United States produces 914.6 billion cubic metres of gas, while Russia produces 638.5 billion cubic metres, Iran produces 250.8 billion cubic metres, China produces 194.0 billion cubic metres, Qatar produces 171.3 billion cubic metres, and Australia produces 142.5 billion cubic metres. Although the Middle East has vast gas reserves, yearly output is now just 686.6 billion cubic meters. This number increases rapidly in the region every year.

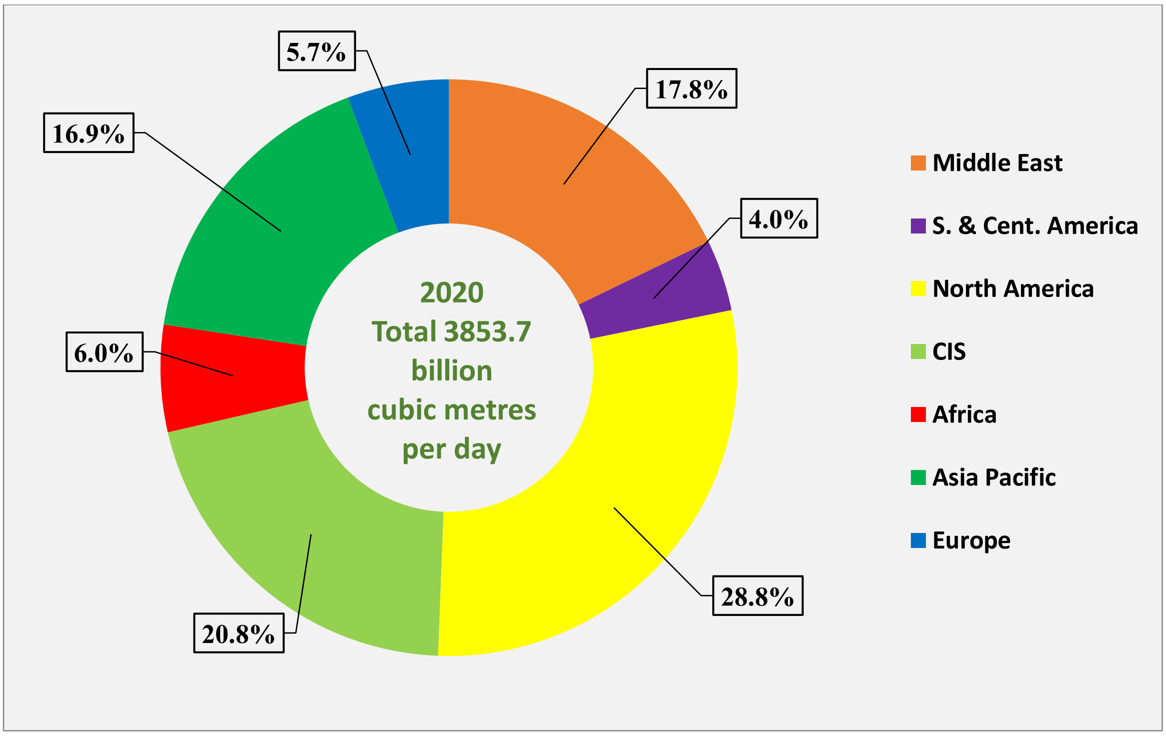


Figure 2. 5. Distribution of daily gas production in the world *(BP, 2021)*

2.7 Consumption of natural gas

In 2019, global natural gas consumption increased by 2% on average, well below the 10-year average and significantly lower than the remarkable surge recorded in 2018. (5.3 percent). Demand increased by 78 billion cubic metres (bcm), led by the United States (27 bcm) and China (24 bcm). As the boost from weather effects and policy-driven coal-to-gas switching in China dissipated, the growth in US and Chinese gas consumption was substantially slower than in 2018. A decrease in the number of abnormally hot and cold days helped Russia's gas usage drop by 10% last year, the biggest drop of any country. Gas production increased by 132 billion cubic meters

(3.4 percent), exceeding consumption increases. With a volumetric rise of 85 billion cubic meters, the US accounted for nearly two-thirds of net worldwide growth, just missing out on 2018's record gain (90 bcm). Strong expansion in Australia (23 billion cubic meters) and China also helped enhance supply (16 bcm).

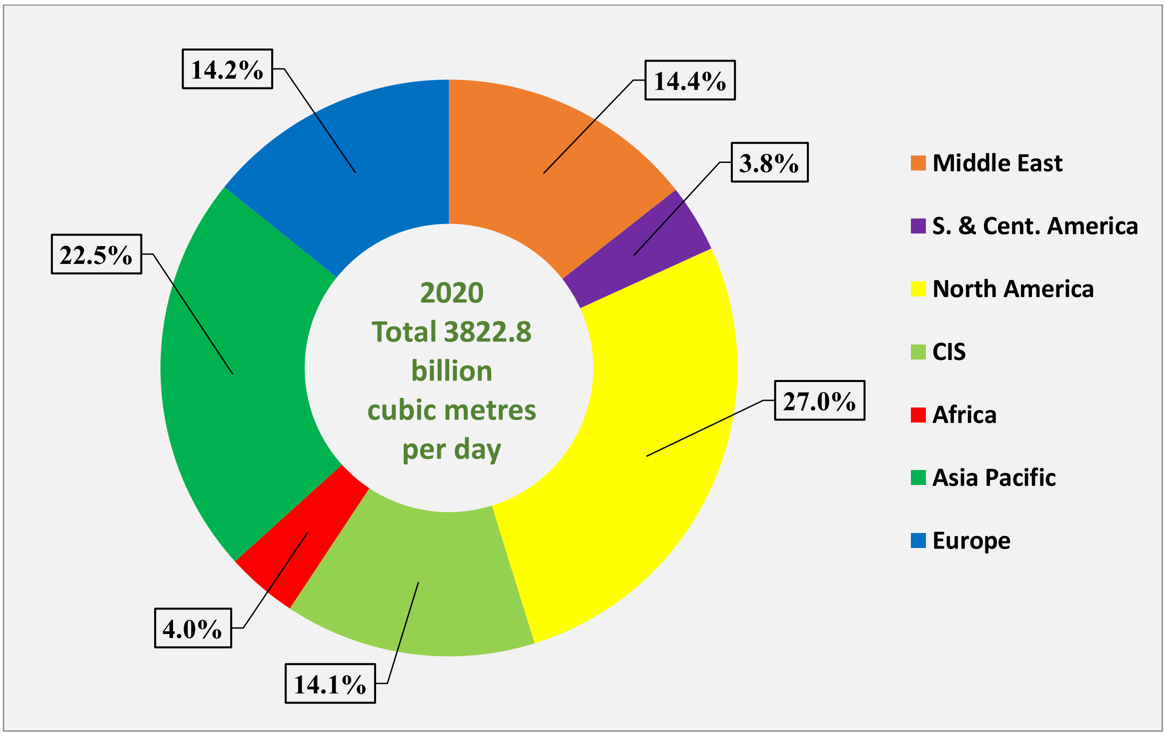


Figure 2. 6. Distribution of daily consumption of gas in the world *(BP, 2021)*

CHAPTER 3: Analysis and description of the prospecting techniques used for the study of sedimentary basins

In both modern and ancient depositional basins, the setting of the plate tectonics is one of the factors that influences the rate at which sedimentary fill accumulates over time. The tectonic setting of any basin can be described in terms of the type of substratum that it has (oceanic, continental, or transitional), its proximity to plate margins (mid-plate as opposed to interplate), and the characteristics of the plate margins that are close by (constructive, destructive, and conservative).

Era	Age	Time Span
Cenozoic and Mesozoic	0-245 Ma	245 m.y.
Paleozoic	245-570 Ma	325 m.y.
Late Proterozoic	500-900 Ma	400 m.y.
Middle Proterozoic	900-1600 Ma	700 m.y.
Early Proterozoic	1600-2500 Ma	900 m.y.
Archean	> 2500 Ma	--

Table 3. 1. Basins characterizations *(WayBack Machine, 2022)*

From the table above, it is possible to see which period the rocks belong to according to their age range, and thus at what interval these rocks were formed. As we know, the formation of rocks is collected in proportion to their age. The rock at the highest level is considered to be the youngest rock, and then older rocks can be seen as it progresses to the lower layers.

If we look at the world map below in the figure, you will be able to determine which age group the sedimentary basins belong to by the rocks that are contained within them. The United States Geological Survey (USGS) created the map shown in figure 3.1, which depicts continents as geological provinces. It is abundantly clear that it has already existed during the Cenozoic and Mesozoic eras, and sedimentary basins typically contain layers that correspond to these time periods. As a result, the rocks that belong to this period can be found in the regions that contain mountain ranges, as well as in the regions of the American continent that contain mountain ranges in Europe and Asia, and as a continuation to the Southeast Asian zone. Later on, during the various periods that comprised the Paleozoic era, the majority of the rocks were dispersed across the earth.

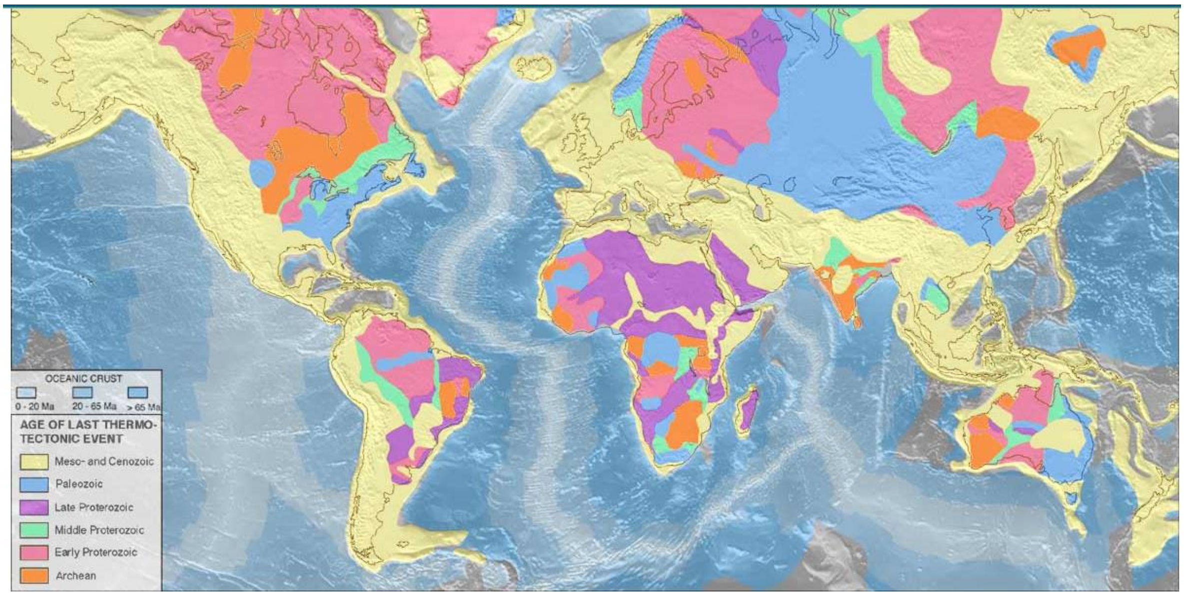


Figure 3. 1. Tectonic map of the World *(WayBack Machine, 2022)*

3.1 Asian sedimentary basins

The world's three largest petroleum basins, the Middle East, West Siberia, and East Siberia, are all in Asia, each covering more than 3 million km^2. They are the most promising and abundant basins on the planet. Asia has about 60 petroleum basins in all. The basement and Palaeozoic filling of most of the basins indicate that they are synclines. The existence of Meso-Cenozoic rifts, troughs, and horst–graben dislocations complicate the basins' unique feature. The sedimentary cover encompasses all Palaeozoic systems and reaches up to 10–12 km in thickness, including marine deposits.

Figure 3. 2. Asian sedimentary basins *(Guoyu, 2011)*

Continental red-colored sediments with well-developed salt and coal-bearing strata characterize the Mesozoic and Cenozoic systems. Both marine and continental sediments have been found to include source rocks. Reservoir rocks are found in sandy deposits, especially in Mesozoic layers, as well as terrigenous and marine carbonate rocks from the Mesozoic and Palaeozoic periods. The weathering of Archaean and Palaeozoic basement rocks has been linked to the formation of specific reservoir types in the crust. There are many coral seals and sealing strata linked with gypsiferous rocks and rock salt. Traps are classified as structural or non-anticlinal. Multilayered oil and gas accumulations are mainly found in Meso-Cenozoic deposits. The petroleum potential of relatively large basins is expected to be high to extremely high, but the petroleum potential of smaller basins is often modest.

3.2 North America sedimentary basins

Figure 3. 3. North American sedimentary basins *(Guoyu, 2011)*

The North American Region encompasses a sizable chunk of the same-named lithospheric plate. To all intents and purposes, this is a continental area, but it is distinguished locally by oceanic crust. A little piece of the Pacific Plate underpins California's coastal regions, forming a conterminous presence of both continental and oceanic crust types. This area is separated into four sections: a central stable shield, the Cordillera Orogenic Belt in the west, the Appalachian Orogenic Belt in the east, the Franklin Geosyncline in the north, and the North America platform in the south.

With some lithospheric fluctuation, the contact between the North American and Pacific Plates runs along the Pacific coast. In the Gulf of California, this contact also runs partially along a spreading axis. In terms of geodynamic evolution, the majority of the North American Region is a passive continental margin. The Gulf of Mexico was once an inner deep-sea basin, but it now lies inside a complicated area of microplate collision and subduction. As a result, Florida and its shelf have divided the deepwater region of the Gulf of Mexico with oceanic crust from the Atlantic Ocean.

Within the boundaries of the North American Region, 93 sedimentary basins have been discovered. These basins are often split into two categories: continental and foreland, but the features of certain basins may be complicated, combining numerous kinds and phases of development. They are categorised in such circumstances based on the prevailing tectonic factor. In this region, 41,000 oil and gas fields have been identified, with over 16,000 of them related with the Gulf of Mexico Basin.

3.3 African sedimentary basins

The African continent is a stable craton composed of merged pieces of Precambrian basement that formed the core of ancient Gondwanaland. Africa's sedimentary basins are classified into two types: sag basins and rifts. The continent is made up of flat, albeit relatively high, Precambrian basement plains made up of igneous and metamorphic rocks of varying ages. These foundation rocks are locally overlain by a blanket of Cambrian to recent shallow marine and continental sediments throughout the continent. Continent-wide volcanic activity accompanied the tectonic changes that culminated in Africa becoming a separate continent during the Triassic Period. Rifting on the eastern side of the continent was established throughout the Jurassic, Cretaceous, and Tertiary periods.

The formation of circular sag basins, such as those found in Africa, has long piqued the interest of researchers. One prominent concept argues that thermal doming over a mantle'hot spot resulted in the erosion of uplifted crustal rock, followed by cooling and crustal collapse, initially into a rift, then gently subsiding to produce a sag basin. It has recently been proposed that crustal sags are caused by 'cold spots' caused by mantle cooling, resulting in downwelling and moderate sagging of the crust. The basins are definitely post-dated by palaeocurrent data, implying that the northerly slope of the palaeo-Tethys was locally interrupted by crustal sag basins in the mid-Cretaceous.

The Cretaceous Period was a pivotal period in African history. The current limits of the African continent were set by the breakup of Gondwanaland and the entrance of the Atlantic Ocean. Some Cretaceous rifts failed as they stretched across Gondwanaland, getting infilled with thick sequences of sediments that frequently featured organic-rich muds put down in confined freshwater–marine habitats. Failed rifts are distinguished by excessive heat flow caused by crustal weakening. As a result, these failed rift basins are frequently major petroleum provinces.

Epicratonic rifts, such as Libya's Sirte embayment, are dominated by carbonate reservoirs, but intracratonic rifts, such as those in Sudan and East Africa, are dominated by terrigenous sediments.

Figure 3. 4. Locations of sedimentary basins in Africa *(Guoyu, 2011)*

3.4 European sedimentary basins

The European Region, along with the nearby oceans and seas, is a portion of the Eurasian Plate. This region is well-known for its long history of geological investigation, which has contributed significantly to global geological nomenclature. The plate's northern, western, and southern (Black Sea) peripheries are characterized by the formation of oceanic crust, although the majority of the plate is categorized as continental crust. The continent's northern and western margins form a passive continental margin that is surrounded primarily by thalassocratons from the Atlantic and Arctic Oceans. The Eurasian Plate's southern boundary is in touch with the African Plate and, to a lesser extent, the Arabian Plate, both of which are being subducted beneath the Eurasian Plate.

The European Region is made up of various structures. In the field of continental crust formation, two types of tectonic features have been identified: platforms with varying basement ages and movable orogenic bands representing variable ages of collision of present-day and ancient lithospheric plates. The nappe-thrusted formations, intermontane depressions, and foredeeps make up the orogenic belts.

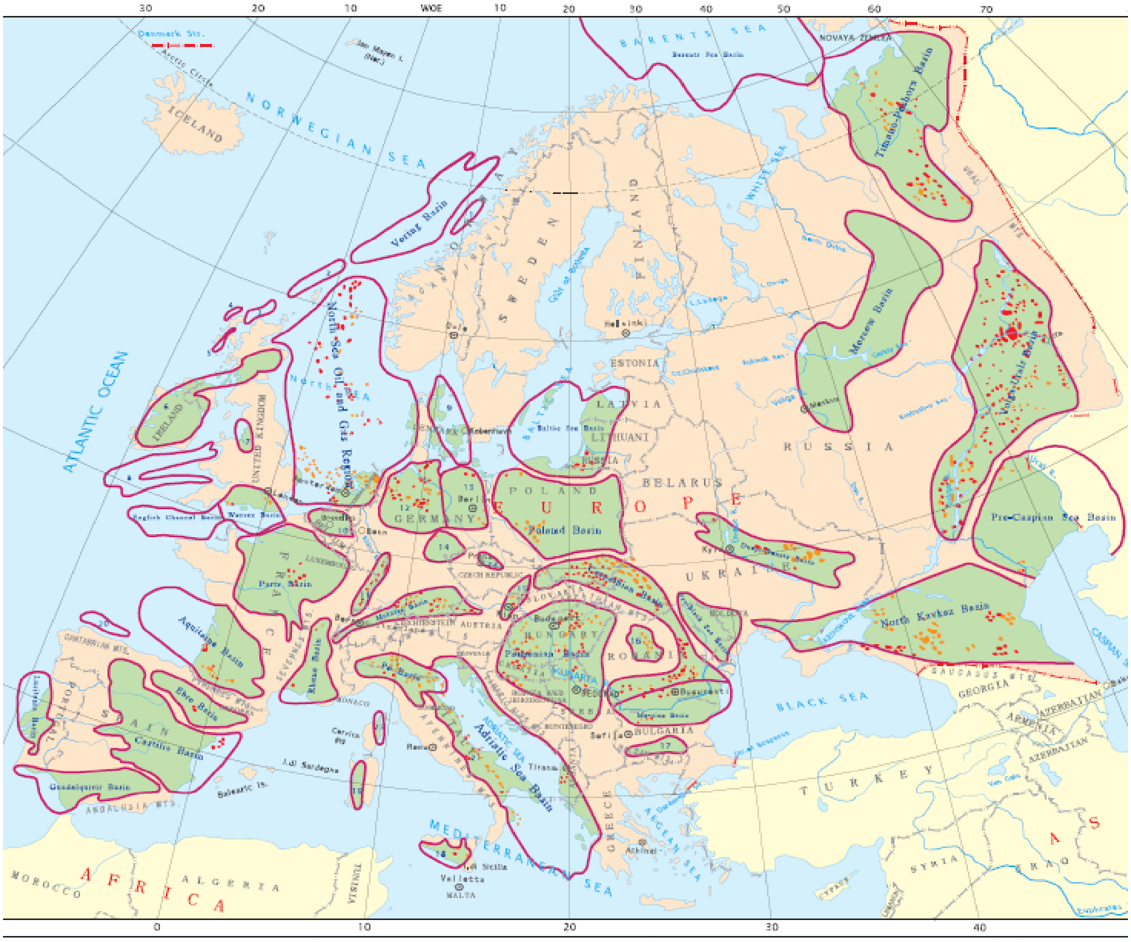


Figure 3. 5. European sedimentary basins *(Guoyu, 2011)*

The platforms are split into two categories: ancient (Precambrian) and young. East European, Barents–Kara, and speculative Eria platforms are among the ancient platforms, as are epi-Baikalian platforms such as Timano–Pechorsky, Mid-European, Moesian, and Apulian. The epi-Hercynian West and South European platforms are young, as are the Central Eurasian (Scythian) and epi-Caledonian platforms of the British Isles.

During the Hercynian orogeny, the Mid-European Orogenic Belt evolved. Within it, many sedimentary basins have formed. This belt runs from Iberia to Dobrudzha before merging with the Uralo-Okhotsk Orogenic Belt. It is the foundation of the West European platform. Intermontane depressions of Upper Silesian type developed inside the outcropping orogenic belt and were filled with Upper Carboniferous deposits. Along the outcropping orogenic belt, a marginal trough formed of Upper Carboniferous rocks can be traced. During the Hercynian orogeny, the Ural Orogenic Belt was also developed. The Mediterranean Orogenic Belt runs from Gibraltar to the

European Region's Caucasus. Deep-water basins are being formed in the Atlantic Ocean's abyssal zones, which may become a prospective location in the future (*Vysotsky et al., 1995*).

3.5 South American sedimentary basins

The South American region consists primarily of the western part of the same-named lithospheric plate, which contains a coastline area, shelf, continental slope, and a piedmont equivalent to ancient continental crust. The sedimentary cover consists of Ceno-Mesozoic strata with thicknesses ranging from 2000 to 10,000 m. Sandstones, limestones, tuffs, and conglomerates make up reservoirs.

The sedimentary basins are modest to medium in size, covering 12,000–200,000 km2. Among the piedmont platforms, the old Brazilian (craton) and young Patagonian (cratogene) platforms can be distinguished. The majority of the continent is occupied by the Brazilian Platform, which has a Precambrian basement. Archaean rocks constitute the Guiana Shield, the basement's northernmost uplift. The West Brazilian and Guiana Shields are separated by the Amazon Syneclise.

The Andes Orogenic Belt runs along the Pacific Coast and borders the Brazilian and Patagonian platforms in the west. The western (Pre-Pacific) zone formed during the Cenozoic and corresponds to the late Alpine tectogenesis cycle. It is made up of Palaeozoic and Mesozoic deposits that have been intruded by Late Cretaceous and Cenozoic rocks. The zone is represented by cordilleras and troughs that partially occupy the continental slope, as well as slopes of deep-water trenches and basins. The eastern zone is made up of rocks from the pre-Alpine and Alpine periods.

Individual portions of the orogenic belt – South (Patagonian), Central, and North Andes – are positioned transverse to each other to form a zonal pattern. Changes in the structural complexes that constitute the cores of the ancient tectonic components, as well as the time of the related orogenic elements, trace it laterally. The position of regional fault zones determines the boundaries between the segments.

Figure 3. 6. South American sedimentary basins *(Guoyu, 2011)*

3.6 Australian sedimentary basins

The Indo-Australian Plate is mostly represented by the region of Australia and Oceania. Throughout their collision, the Pacific Plate is being subducted beneath the Indo-Australian Plate. Only the continent's north and east have active margins. The continent of Australia is made up of two major tectonic factors. These are the Tasmanian Orogenic Belt and the old Australian platform. The Australian platform (craton) encompasses the western and central regions of the continent, as well as the southern half of New Guinea and the ocean between them (Arafura Sea). Early Precambrian basement outcrops can be found in one-half of the craton.

Upper Proterozoic deposits begin the sedimentary cover sequence. The Palaeozoic rocks are represented by clayey-carbonate strata, whereas the Mesozoic and Cenozoic rocks are represented by sandy–clayey strata with frequent carbonaceous intervals. There are many depressions and a parallel foredeep in the Tasmanian Orogenic Belt. Within the Australia and Oceania region, 43 sedimentary basins with significant hydrocarbon potential have been found, with 14 oil and gas fields discovered.

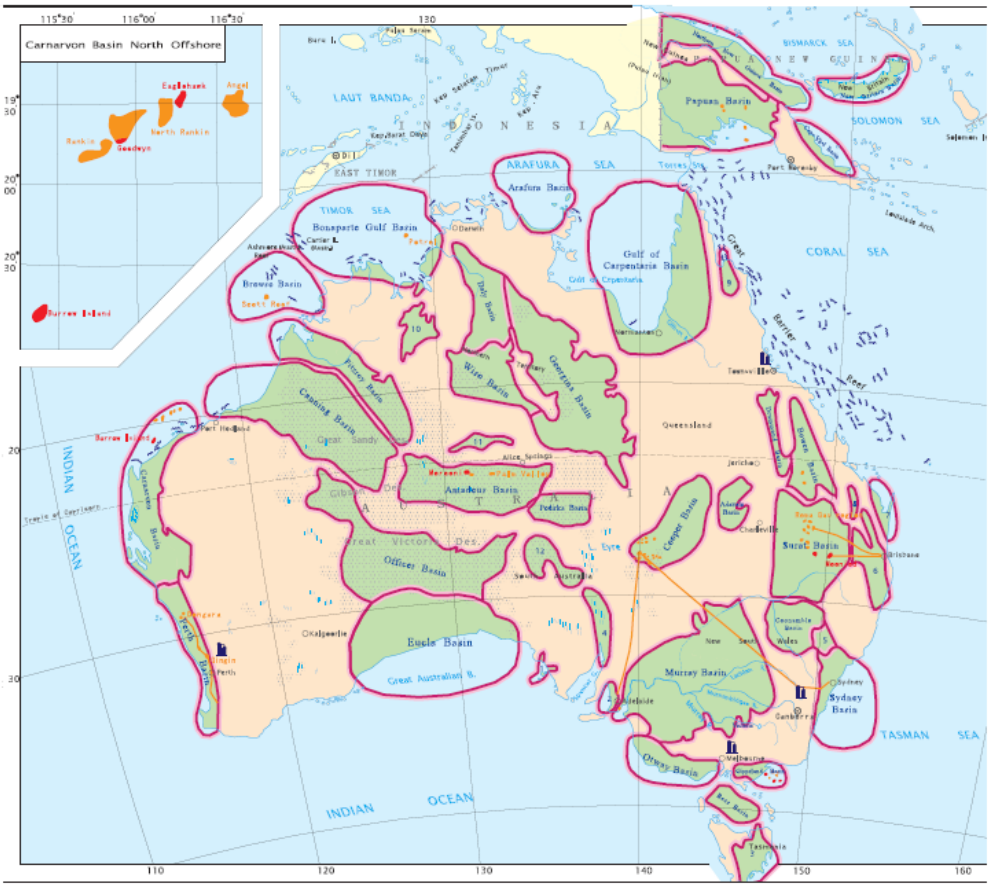


Figure 3. 7. Australian sedimentary basins *(Guoyu, 2011)*

CHAPTER 4: Analysis and description of drilling techniques for Oil and Gas extraction in Oilfields

4.1 Introduction

Natural gas and crude oil are complex mixes of hydrocarbons, nonhydrocarbons, and trace components that are preserved in sedimentary rocks. Depending on the geographical location of the hydrocarbons, different types of drilling methods can be used. Drilling is the best approach for extracting these resources from deep deposits. A well is formed by drilling a hole into the earth's crust with a drilling rig that spins a drill string with a bit attached. There are several drilling methods, each with its own set of advantages. The different types of formations, geographic locations, types of soil, and other factors are taken into consideration while selecting the appropriate drilling method and platform for oil and gas exploration. The following is a list of the five most popular drilling techniques utilized in the process of obtaining oil and gas from under the surface of the earth:

- Percussion or Cable Drilling
- Rotary Drilling
- Dual-Wall Reverse-Circulation Drilling
- Electro-Drilling
- Directional Drilling

4.2 Percussion or cable drilling

Percussion drilling is a common manual drilling technique that involves attaching a pounding bit to a long cable and lowering it into a large open hole. The driller utilizes a tripod to support the instruments in this method, which is also known as cable drilling. The movement of moving the bit back and forth loosens the dirt in the borehole, which is subsequently removed with the assistance of a bailer. The bit is withdrawn at intervals while the cuttings are floating in water, which is subsequently pumped to the surface. A steel enclosure prevents the hole from collapsing momentarily and also protects the hole from groundwater pollution. After installing a permanent screen and casing, the temporary configuration will be deleted.

This drilling method is ideal for unconsolidated and consolidated formations such as sand, silt, sandstone, and even gravel. Manual percussion can penetrate to depths of around 25 meters.

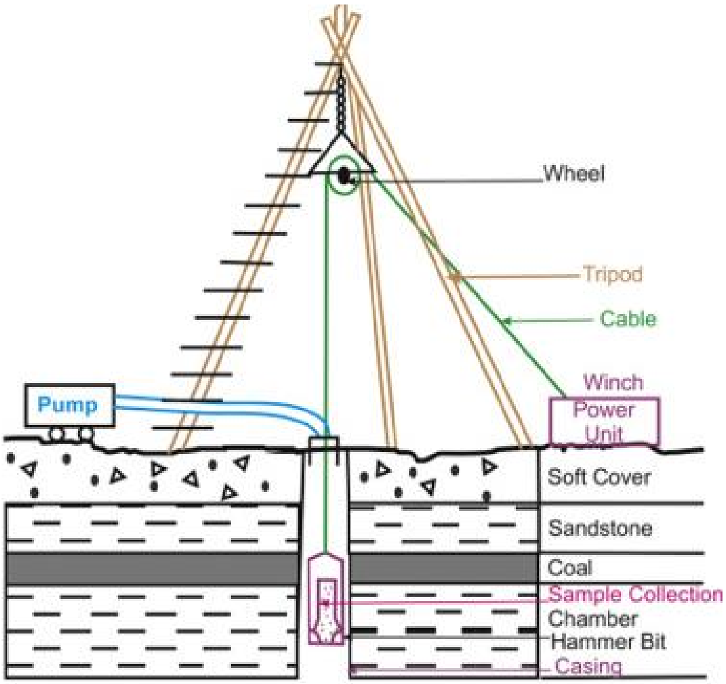


Figure 4. 1. Percussion drilling illustration *(M.Rafiqul Islam, 2021)*

4.3 Rotary drilling

Rotary drilling is also one of the most frequent methods of drilling, particularly for excavating exploration and production wells with depths exceeding five miles below earth. Lightweight drills are employed in this technology to drill low-depth wells on land. Then, various sizes of rotary mobile and floating drills are employed to drill exploratory wells.

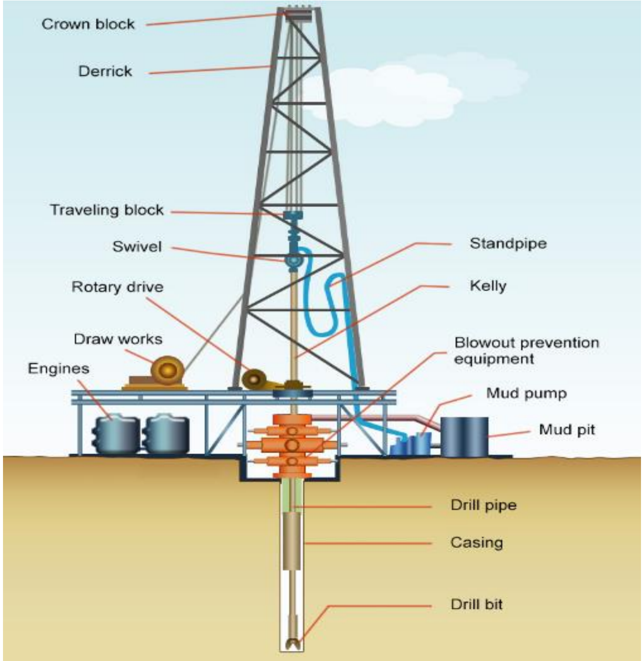


Figure 4. 2. Rotary drilling *(Financial Energy Review, 2020)*

The machinery is located on a platform with a 40-meter-high derrick and includes a rotary table, a convenient engine, a mud mixer, and an efficient injector pump. It also has a winch and pipe pieces that are 27 meters long. The square kelly, which is attached to the drilling pipe, is then directed by the rotating table. The pipe's mud swivel is then linked to blowout preventers. Pipes are known to revolve at speeds ranging from 40 to 250 rpm when drilled with drag bits, sharp cutting edges, or rolling cutters with powerful teeth.

Fluid circulation inside the pipe then removes the cuttings. When employing air-based drilling fluids instead of water-based ones, the penetration rate is quicker. In this case, a drag bit can drill through unconsolidated sediments whereas a roller bit can drill through consolidated rock. Depending on the hardness of the formation material, the drill's total rotation speed can be raised or lowered.

4.4 Dual-wall reverse-circulation drilling

A form of rotary drilling known as dual-wall reverse-circulation employs the use of two drill pipes that are arranged in a concentric fashion in order to provide a regulated flow. In order for the drilling fluid to reach the bottom of the bit, it must first be pushed via an outside swivel. The fluid will then ricochet upward into the main pipe.

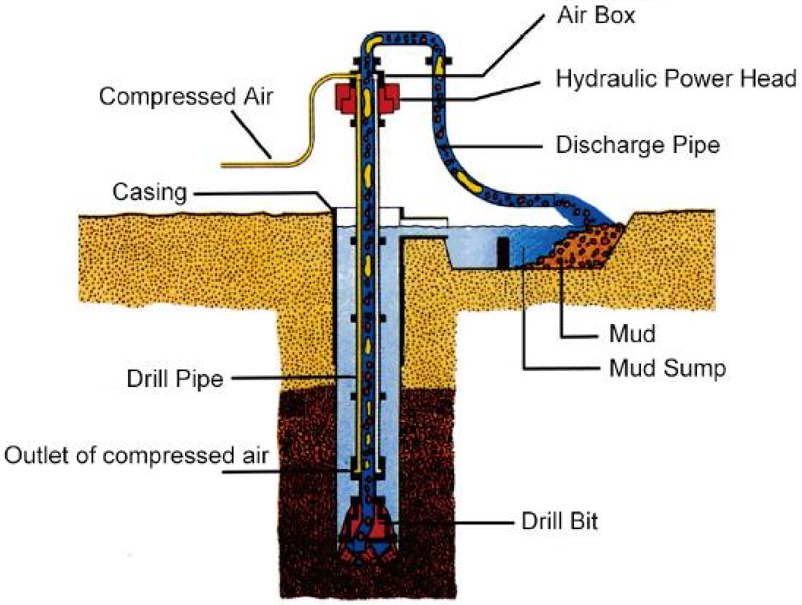


Figure 4. 3. Reverse Circulation Drilling System (RCD) *(Ougan Group, 2021)*

With the assistance of a surface swivel and the passage of an internal pipe, all of the cuttings are transported upward. Additionally, the procedure permits the collecting of geologic samples, with the samples often being conveyed through the cyclone that is formed at the surface. This approach may be used in conjunction with rotary drilling as well as percussive drilling techniques. Within an area that can be regulated, the fluids are cycled, and any and all cuttings can be retrieved at any moment. This approach does not call for surface casing either, making it suitable for use with any and all sorts of geologic formations.

One of the most important advantages of using this approach is that it allows for a high level of sample recovery. Additionally, the approach enables rapid penetration in alluvial as well as fissured rock. In addition to this, it is beneficial in that it contributes to the delivery of an accurate assessment of the aquifer yield from the depths of the formation.

4.5 Electro drilling

Electric motors are used to power rotary tables, winches, and other similar pieces of equipment in this approach, which results in more operational flexibility as well as the ability to drill via remote control. These drills are innovative techniques for oil and gas exploration because they link the motor above the bit rather than below the hole. As a result, the drill bit receives more direct power from the engine.

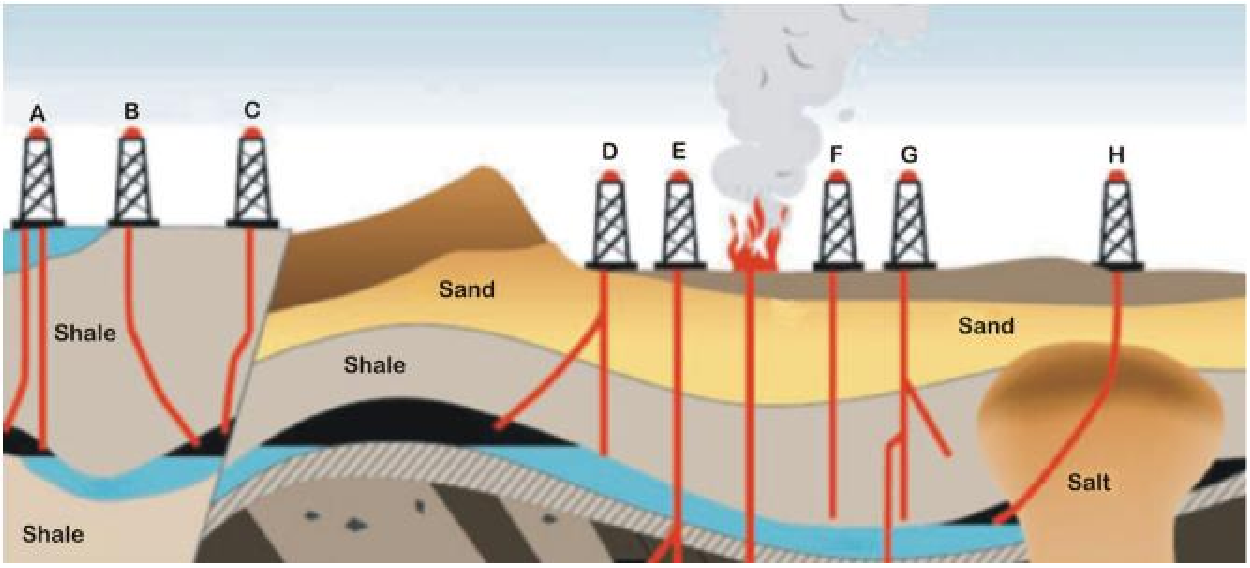
The electro-drilling technology has proven to be effective in difficult geological circumstances, particularly those that need the utilization of weighted mud or mud combinations. Electro-drilling has made its mark in a variety of locations, including Turkmenistan, Azerbaijan, and Ukraine. These countries are eager to adopt electro-drilling on a larger scale to increase their energy and material consumption cost reductions.

This method incorporates a wide range of drill-bit rotational speeds, and it combines the rotary and hydraulic-motor drilling approaches for optimal performance. This procedure is also capable of utilizing a variety of cleaners for boreholes. Using this technology, one may even conduct controlled drilling of deviated boreholes.

4.6 Directional drilling

The rotary drilling method is essentially an extension of the directional drilling method, which directs the drill along a curved route as the hole is deepened. Directional drilling is actually an extension of the rotary drilling method. Oil explorers can use directional drilling to access reserves that can't be mined using the more traditional method of vertical drilling. Because several wells may be drilled in any direction from a single platform, the primary driving is a reduction in associated costs. This makes it possible to access underwater reserves, and now, with the help of computers to direct the autonomous drilling machines, this can be done without having to connect and separate parts of the pipe.

Explosive drilling and flame piercing are two additional methods that are used in some drilling scenarios. Abrasive drilling is one more drilling method that makes use of an abrasive material for driving pressure to cut through the substrata. Other drilling methods include explosive drilling and flame piercing.



A – Multiple wells offshore **B – Shoreline drilling** **C- Fault control**

D – Inaccessible location **E – Stratigraphic traps** **F- Relief well**

G – Straightening & sidetracking **H – Salt dome**

Figure 4.4. Applications of directional drilling *(Tianshou Ma, 2016)*

4.7 Horizontal drilling

The process of horizontal drilling involves drilling a well from the surface to a subsurface location just above the target oil or gas reservoir known as the "kickoff point," then veering the well bore from the vertical plane around a curve to intersect the reservoir at the "entry point" with a near-horizontal inclination, and finally remaining within the reservoir until the desired bottom hole location is reached. This is referred to as horizontal drilling. An inclination of about sixty degrees can be reached when drilling conventionally directed wells.

Inclinations greater than 60 cause a multitude of drilling challenges, which leads to a significant increase in the overall cost of digging the well.

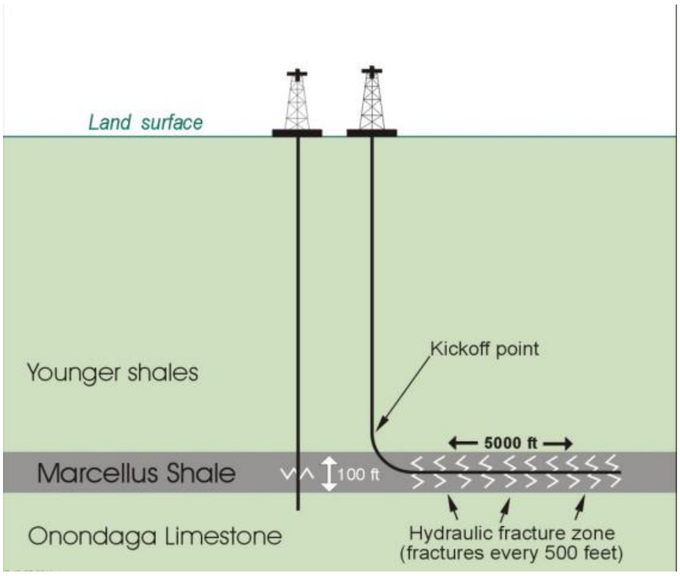


Figure 4. 5. Combination of horizontal and vertical drilling *(Soeder, 2012)*

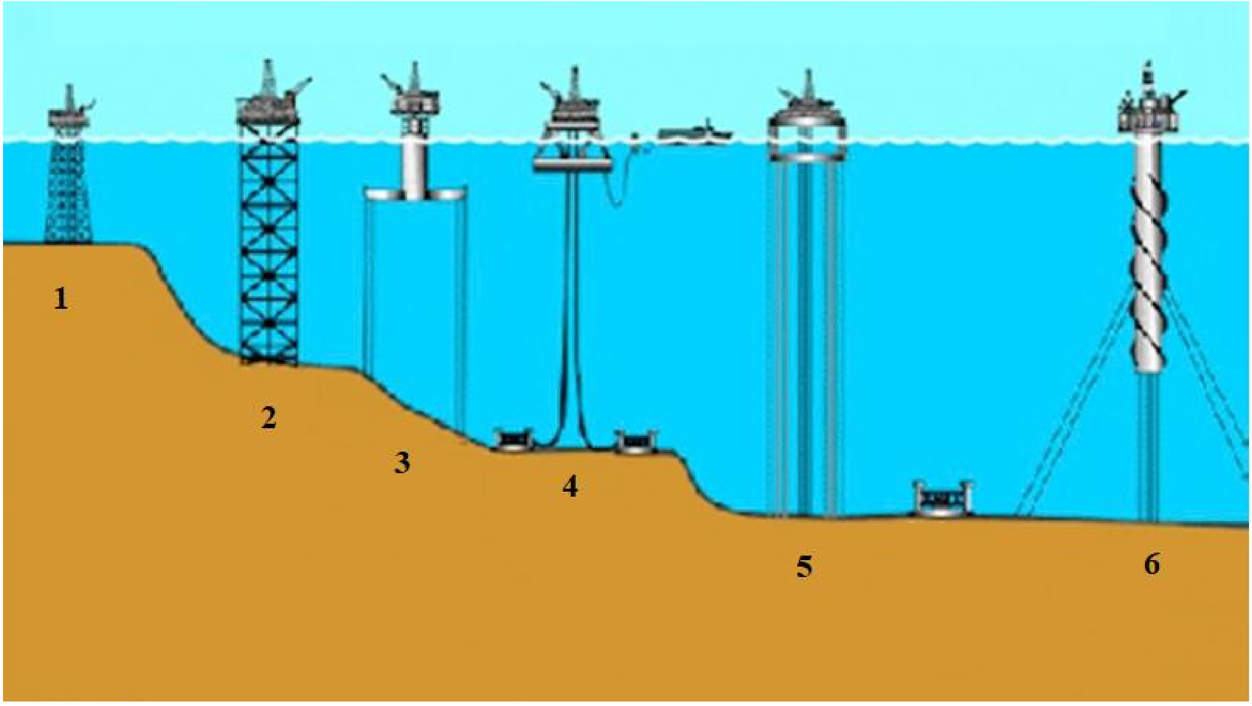
However, drilling highly deviated wells and horizontal wells both have distinct benefits over conventional well drilling. (1) increasing the drainage area of the platform; (2) preventing problems caused by gas coning or water coning; (3) increasing the penetration of the producing formation; (4) improving the effectiveness of enhanced oil recovery (EOR) techniques; and (5) increasing productivity in fractured reservoirs by intersecting a number of vertical fractures.

As we know, hydrocarbon extraction is carried out in the oil and gas industry by drilling wells using various drilling methods. It would be more appropriate to use these wells not only for the extraction of natural resources such as oil and gas, but also as a potential source of geothermal energy in the future. The use of abandoned wells to generate renewable energy will lead to the widespread use of both energy consumption and clean energy.

CHAPTER 5: Decommissioning processes of oil and gas structures

5.1 Decommissioning

The process of terminating operations at an offshore oil and gas platform is known as decommissioning. During decommissioning, the platform is often dismantled fully and the seabed is restored to its unobstructed prelease condition. However, there are alternative possibilities, such as reefing the platform structure's submerged areas. The method of transforming disused oil and gas platforms into artificial reefs is known as rigs-to-reefs (RtR). Oil and gas platforms in the United States (U.S.), Brunei, and Malaysia have all been used to produce biotic reefs. Decommissioning always entails the complete removal of topside amenities, leaving just the jacket as a possible reef.



1. Fixed platform (FP, to 1500 ft)
2. Compliant tower (CT, 1500-3000 ft)
3. Sea Star (Sstar, 500-3500 ft)
4. Floating Porduction Systems (FPS, 1500-6000 ft)
5. Tension Leg Platform (TLP, 1500-7000 ft)
6. SPAR platform (SP, 2000-10000 ft)

Figure 5. 1. Various platform production structures *(Ann Scarborough Bull, 2018)*

A jacket is a steel support structure that sits on the ocean floor and has columns or legs that stretch up through the water surface. Pilings are hammered into the seafloor through the jacket's tubular legs to keep the garment in place. Most permanent platforms, according to government authorities at the Bureau of Safety and Environmental Enforcement (BSEE), are normally situated in shallow water, but some 1400 feet. Deeper water production facilities are anchored to the bottom by floating structures without jackets.

5.2 Platform removal

Platform Infrastructure	Decommissioning options
Topsides	Leave in place (repurpose)
	Remove
Platform jackets	Leave in place
	Relocatefor artificial reefing
	Partial removal
	Complete removal
Floating Storage Production and Offtake facilities (FPSO) and Risers	Remove
Concrete Gravity Structures	Leave in place
	Remove
Sea bed Wellheads, Manifolds and Valves	Remove
Wells	Plug and abandon
Mattresses	Leave in place
	Remove
Pipelines	Cut ends and leave in place
	Trenchy and bury
	Remove

Table 5. 1. Decommissioning options for oil and gas infrastructure

Topside (the facilities above the waterline) and substructure are two different elements of a platform for decommissioning reasons, and they may be separated into two distinct categories: topside and substructure. Decommissioning entails removing all operational components from the ship's topside facilities and transporting them to land for recycling or partial re-use. Generally, 15 feet below the mudline, the substructure supporting jacket is broken, then dragged from the seafloor, dismantled, and barged to shore to be sold as scrap or repaired for installation at another place, with some parts ending up in a landfill.

5.3 Requirements for decommissioning

OCSLA regulatory *(OUTER CONTINENTAL SHELF LANDS ACT, 2021)* and lease requirements for decommissioning offshore platforms are intended to reduce the environmental and safety risks associated with leaving unused structures in the ocean, as well as the potential for conflicts with other federal OCS users (i.e., commercial fishing/aquaculture, military activities, transportation industry, and other oil and gas/renewable energy operations). Decommissioning an offshore platform for total removal typically entails the following steps:

1. plugging all wells supported by the platform and severing the well casings/conductors 15 feet below the mudline;

2. cleaning and removing all production and pipeline risers supported by the platform;

3. removing the platform from its foundation by severing all bottom-founded components at least 15 feet below the mudline;

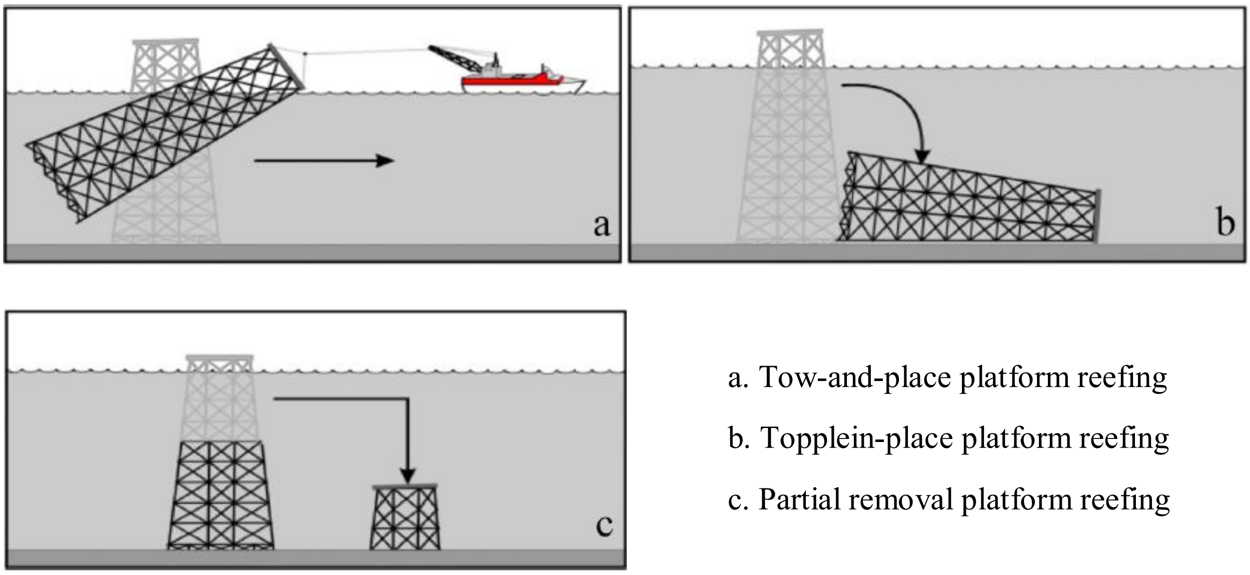
4. Disposal of the platform at a scrap yard or fabrication yard, or placement of the platform at an artificial reef site;

5. Site clearance verification at the platform position to verify that no debris or potential impediments to other OCS users remain.

OCSLA regulations, as managed by BSEE, require operators to apply for approval of the platform removal approach prior to removing the platform. To meet National Environmental Policy Act (NEPA) requirements, the Bureau of Ocean Energy Management (BOEM) produces an environmental assessment on behalf of BSEE for each removal application. As a condition of permit approval, BSEE verifies that the evaluation is adequate and enforces any necessary protective mitigating measures.

5.4 Implementation of the rigs-to-reefs program

Many variables influence the timing of future decommissioning efforts. It is determined by the state or federal lease's duration limit and requirements, as well as the geology type and size of the oil and/or gas reservoir. The pace of petroleum production and consequent reservoir depletion, as well as the ability to convey the commodity to market. Thus, the market value of the oil or gas, the possible resale or reuse value of the structure, and if the platform may serve an expanded purpose for the operator, such as a collecting or pass-through station for production from adjacent platforms. So, when all of these elements are considered, it is not always cost effective for industry to turn a decommissioned platform into an artificial reef. The size of the structure, sea depth, distance from shore, and distance to the eventual reef location (Fig. 5.2a) all determine whether a decommissioned platform becomes a reef.



a. Tow-and-place platform reefing

b. Topplein-place platform reefing

c. Partial removal platform reefing

Figure 5. 2. Platform reefing methods *(Ann Scarborough Bull, 2018)*

Methods a and b often use explosives to severe steel jacket legs below the seafloor. Methods b and c often use mechanical tools to severe steel jacket legs either below or above the seafloor. Method c may or may not include placement of shallow water severed jacket on the seafloor as additional reef material.

The decommissioning process is divided into three basic steps and several sub-stages: planning, permitting, and execution. RtR refers to a group of decommissioning approaches that involve leaving a portion of the decommissioned platform structure in the maritime environment. Deepwater dumping is sometimes regarded a different option from shallow-water reefing, however the functional implications (placement of hard substrate into a marine ecosystem) may be deemed identical from an ecological standpoint.

There are three approaches for transforming an old oil and gas platform's subsurface jacket portion into an artificial reef. Partially removing the platform (Fig. 5.2 c) normally uses non-explosive methods to remove the platform, which is commonly done around 85 feet below the mean waterline. Partial removals result in higher reef profiles and reduced stress to and loss of habitat by related reef creatures as compared to toppling in place (Fig. 5.2b).

5.5 Current status and future trends of global decommission

More mature oil and gas producing zones, such as the North Sea, Asia-Pacific, and the US Gulf of Mexico, have emerged. In Asia-Pacific, 20% of offshore facilities are over 20 years old and have outlived their design lives. In the United Kingdom, one-third of active platforms are over 30 years old and will be decommissioned in the near future. During this time, about 700 fields will halt output. This results in a massive cost for the Oil Company. The expected cost of decommissioning is rising year after year.

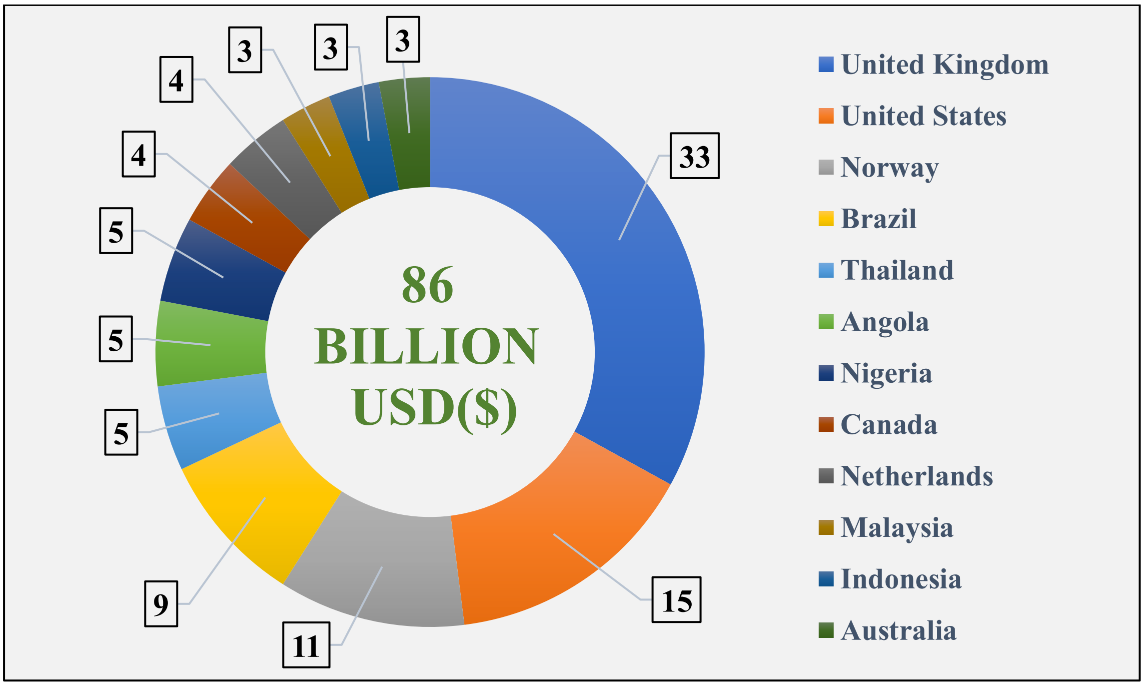


Figure 5. 3. Top 12 spender by country *(Li Jia, 2019)*

The top 12 spenders by country will spend US$86 billion over the next ten years, according to Wood Mackenzie research. From 2018 to 2022, the top ten corporations are estimated to spend $14 billion. Wood Mackenzie predicts that worldwide decommissioning spending would reach $38 billion between 2018 and 2022, up from $18 billion in the previous five years. These investments are small in terms of worldwide offshore development, accounting for around 2% of overall CAPEX in the oil industry in 2017. The wave of decommissioning is on its way. Beyond 2022, the remaining decommissioning expenditures for offshore fields will be US$340 billion.

5.6 Decommissioning – case of Chevron

Asia Pacific is a mature area, with over 1000 units functioning past their 25-year design life. In Asia Pacific, decommissioning is a new problem. Chevron has taken a different approach in this regard. For this case study, we used Chevron-operated Contract Area 1 in the Gulf of Thailand.

The expected decommissioning liability for chevron-operated contracts is US$ 1 billion over the following 16 years, beginning in 2018. However, there is room for major cost reductions.

- Knowledge transfer between specialists, regulators, and operators

Operators, particularly those with substantial expertise in offshore asset retirement, can contribute to the development of legislation. Chevron has worked with Thailand's mining ministries, gaining expertise with decommissioning activities and moving up the learning curve. The cost of wells, wellhead platforms, and pipelines might be reduced by up to 15%.

- Selecting the most appropriate commercial and contracting approach.

Furthermore, the project management team may select the optimum contract combination to prevent cost overruns based on the company's current status. Chevron integrated internal resources, supervised the whole disposal process and decommission management, and obtained considerable cost savings on abandonment. Chevron has around 4000 wells and 300 platforms under contract. Batch decommissioning provides cost-saving potential in locations with a significant number of aging wells and platforms. Chevron has also lowered the rig rate dramatically, which has helped to cut well P&A expenses. Through the foregoing strategy, further cost savings of up to 40% on wells, 20% on wellhead platforms, and 10% on pipeline can be realized.

- Adoption of cost-cutting disruptive technologies.

Emerging cost-effective disruptive technologies, such as rig-to-reef and thermite plugs, might further lower costs. For example, employing a thermite plug solution might cut setup time in half. The plugging is a portion of the defunct enterprise. Instead of many visits with drill pipe to wash, cement, and seal the well, the thermite plug solution may be delivered through wireline.

CHAPTER 6: Conversion of abandoned oil and gas structures into geothermal energy production

6.1 Introduction to geothermal energy

Geothermal energy is a consistent and self-sustaining source of renewable energy that contributes significantly to the world's future energy balance. Nonetheless, despite its tremendous potential, the geothermal sector's total contribution to world power generation remains relatively tiny.

Geothermal energy is one of the most plentiful renewable energy sources, and many believe it to be a steady and independent supply. Deep geothermal resources are widely available across continents and can assist governments in becoming less reliant on energy imports and establishing a more diverse basis in their future energy mix. According to the International Energy Agency (IEA), geothermal energy output increased at a 2.3 percent yearly pace between 1990 and 2016, rising from 28.6 TWh to 51.8 TWh. Geothermal is not on track, according to the IEA's 2 C Scenario (2DS), which lays out an energy system deployment pathway and an emissions trajectory consistent with at least a 50% chance of limiting the average global temperature increase to 2 C (reducing CO2 emissions by nearly 60% by 2050, compared to 2013). As a result, the IEA advised in 2017 that strategies be developed to overcome technology-specific problems in order to achieve quicker growth and that policies addressing pre-development risks for geothermal energy be improved.

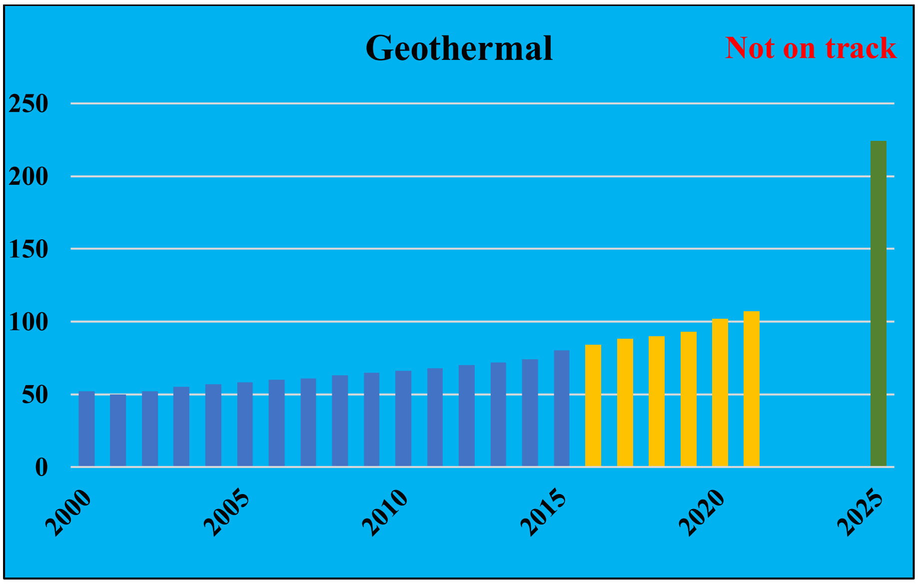


Figure 6. 1. Geothermal technologies not on track to reach their 2DS target *(Energy technology perspectives 2017 excerpt, 2017)*

According to recent data, as many as 20 nations use geothermal energy to generate power, totaling 73.7 TWh/year. Furthermore, roughly 163 TWh/year of geothermal energy has been used for direct applications (cooling, heating, and other processes) in dozens of nations. Between 2016 and 2020, geothermal power generating capacity increased by 27 percent (3.65 GW), with significant growth reported in Turkey, Indonesia, the United States, and Kenya. The use of geothermal energy is predicted to increase steadily, with an estimated 800-1300 TWh of electricity generation and 3300-3800 TWh/year direct thermal consumption by 2050.

Depending on the temperature of the geothermal resources, the generated fluids can be utilized for heating (and cooling) and/or power generation in geothermal energy extraction.

6.2 Characteristics of oilfield geothermal resource

Geothermal resources can be divided into three categories: low, intermediate, and high temperature resources. This classification reflects the availability of various resources that can be used at different temperatures, such as spacing heating/cooling, industrial drying, power generation, and other applications. The following categories will be used among a variety of classification methods in this case.

a) High temperature resource: greater than 150 °C.

b) Intermediate temperature resource: between 90 and 150 degrees Celsius.

c) Low temperature resource: between 30 and 90 degrees Celsius.

Oilfield geothermal resources, which co-exist with hydrocarbons in sedimentary basins, fall into the intermediate to low temperature category, with produced fluid temperatures ranging from 65 °C to 150 °C.

6.3 Geothermal exploitation methods

Various approaches for deep geothermal energy utilization have been presented in the literature, some of which were inspired by the necessity to devise methods appropriate for circumstances where the heat is available but the formation's permeability and/or porosity are not.

- Hot dry rock (HDR)

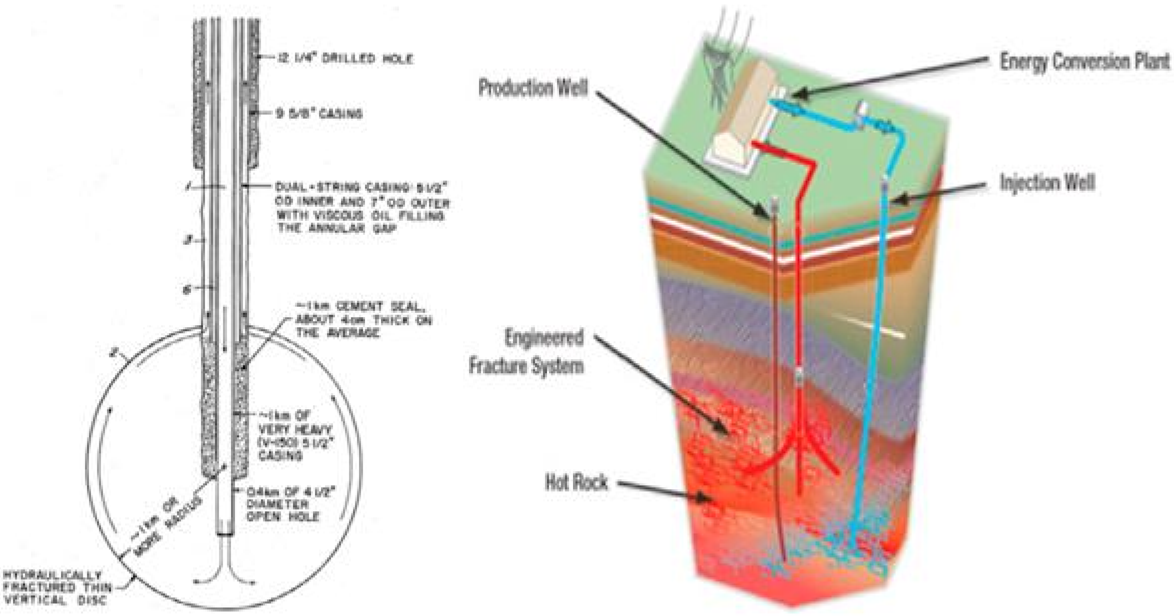


Figure 6. 2. HDR concept *(Falcone, 2018)*

The original HDR idea and its derivations are based on the artificial fabrication of hydraulic connection between injection and production wells (Fig. 6.3), which is the origin of the present term EGS, which was established earlier. In 1977, a Los Alamos National Laboratory research team tested it for the first time at Fenton Hill. Based on the Fenton Hill experience, the HDR idea was later deployed in Rosemanowes (UK) to handle large-scale rock mechanics tests.

6.4 Open-loop configurations

Geothermal energy may be extracted using either an open-loop or a closed-loop arrangement in EGS. The former necessitates the use of many wells, some of which will be used to inject the working fluid (as injection wells) and others to collect the working fluid (as extraction wells).

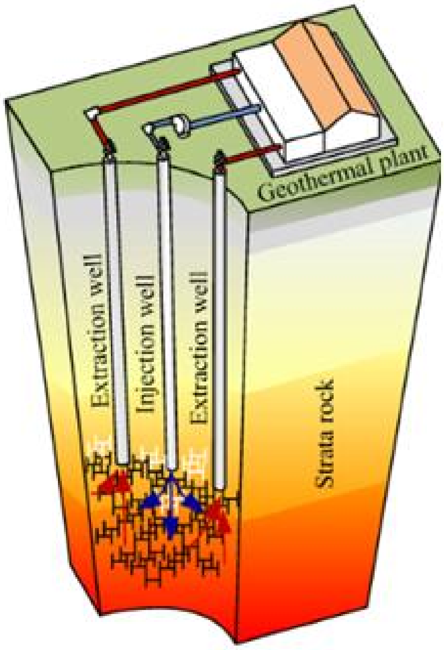


Figure 6. 3. Open-loop geothermal energy extraction *(Jundika Candra Kurnia, 2020)*

Because of the direct contact of the working fluid with the hot rock and the larger heat transfer surface, this design often delivers higher energy extraction. However, it is only possible if at least two wells are close. Otherwise, new wells must be sunk to complete the loops. Furthermore, further fracking may be required to construct flow pathways from the injection wells to the extraction wells.

6.5 The single-well (U-tube) concept

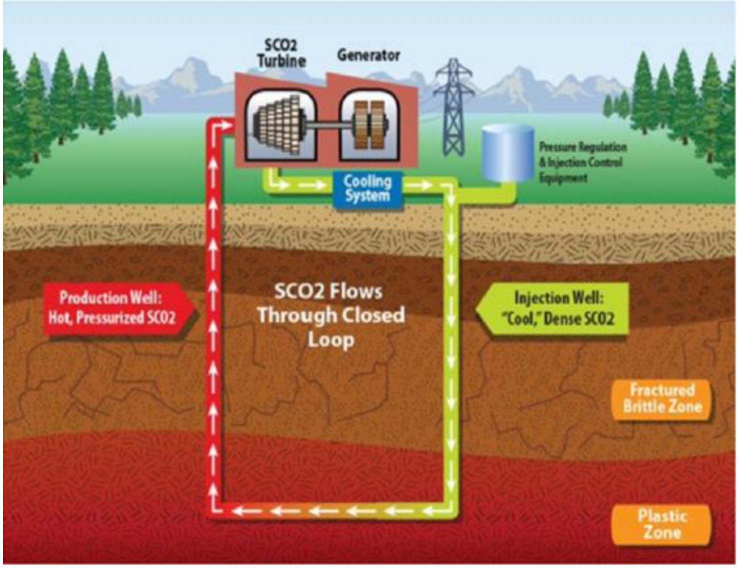


Figure 6. 4. Single-well (U-tube) concept *(Falcone, 2018)*

Geofluids are pumped in a U-shaped wellbore/chamber in the single-well (U-tube) design to collect thermal energy from the subsurface area via direct heating. Isaakidis initially submitted this concept in the form of a patent. A spiral energy harvesting device with a pressurized return passage is installed in the U-shaped wellbore. Gravity pulls geofluids down to gather heat from underground spiral chambers, which they then return to an energy conversion system on the surface. GreenFire has stated that it would begin a demonstration project based on the single-well (U-tube) approach, as shown in Fig. 6.5, in which supercritical CO2 will be used as the geofluid instead of water. GreenFire intends to repurpose a failing hydrothermal well at the Coso KGRA in Inyo County, California, to construct the first field-scale pilot project to create grid-scale geothermal energy without the usage of water.

6.6 Single-well (open-loop) concept

Single-well ideas offer the overall advantage of lowering deep geothermal costs by requiring only one well to be dug. Geofluids are injected and generated through the same well, with or without natural or manufactured cracks, according to the idea. The achievement of high heat flux/thermal output remains a difficulty. The single-well (open loop) approach is based on several components of a well (casing and tubing) linking to production or injection layers, where the layers are separated from one another. The GeneSys project (Fig. 6.6) is the only one in the world that has tested the single-well (open loop) idea for direct geothermal energy consumption. A dual-string single borehole and a hydraulically generated fracture comprise the idea.

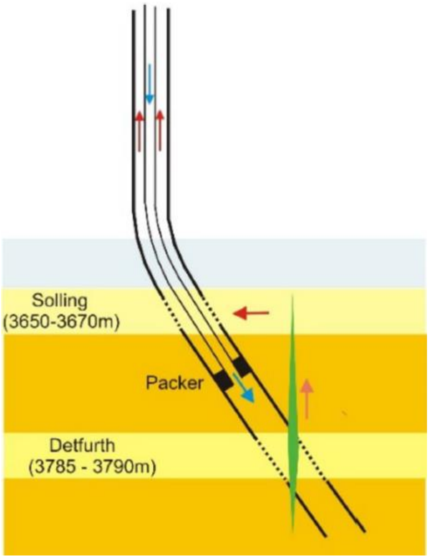


Figure 6. 5. The Genesys concept *(Falcone, 2018)*

Gedzius and Teodoriu presented another single-well (open loop) design. The strategy centered on lowering drilling costs while also developing sustainable technologies and optimizing heat recovery.

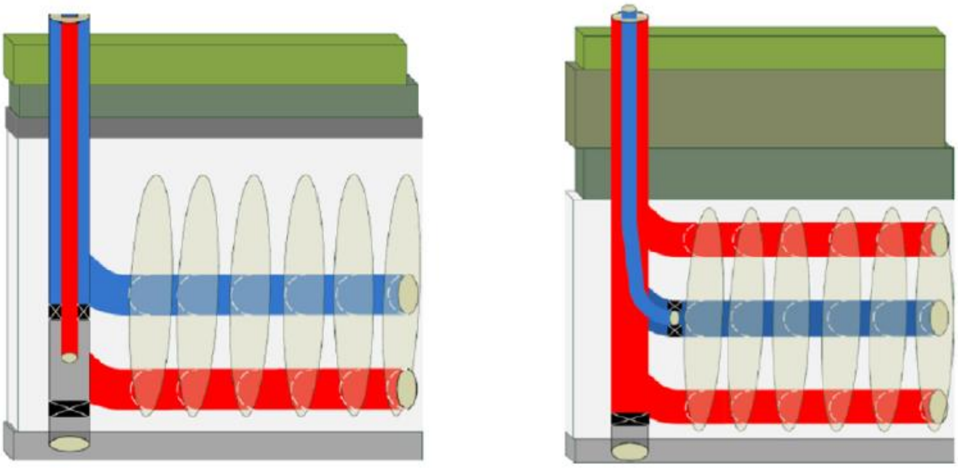


Figure 6. 6. Single-well (open loop) concept with multilateral branch *(Falcone, 2018)*

An open loop system of a single well is constructed by combining two or more horizontal lateral boreholes of adequate length and diameter, each with a sealed casing and open bottom tubing. If there are no natural fissures, hydraulic fracturing can be used to produce artificial fractures that link to one other and to horizontal wells (Fig. 6.7).

6.6.1 USA geothermal resources

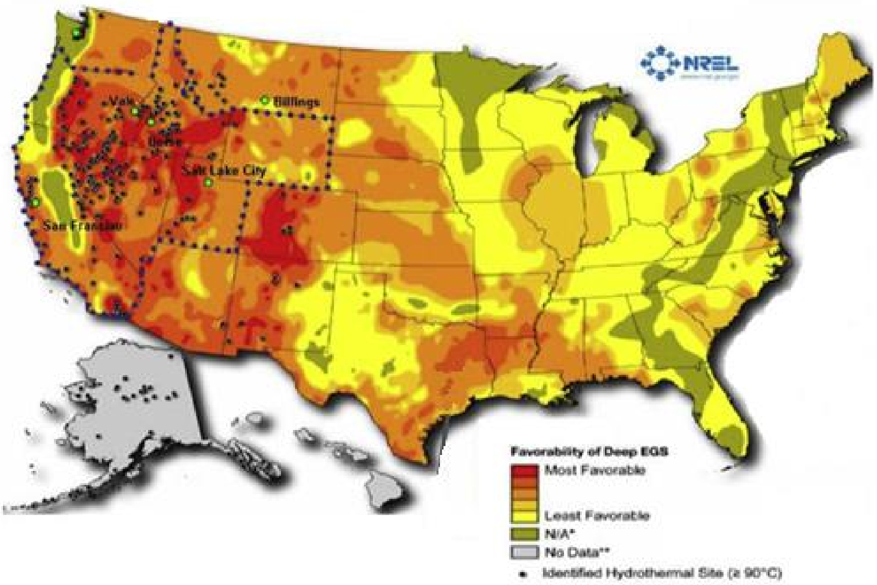


Figure 6. 7. Geothermal resource distribution in USA *(Ruud Weijermars, 2018)*

As of 2015, the United States has 3.7 GW of installed geothermal power capacity, a significant portion of the world's total of 13.3 GW, making it by far the world's top geothermal energy generator. Figure 6.8 indicates that all of the present geothermal power generating capacity in the United States (dotted line) is concentrated in just six western states (CA, NV, UT, OR, ID, WY). These states feature crustal regions with relatively strong local heat flow, which, when combined with local hydrothermal reservoirs, provides optimal circumstances for successful heat extraction.

Wells in the Lightning Dock region generate from a 350 to 600 ft deep hot plume reservoir at well rates ranging from a few hundred gpm to 1200 gpm, often at temperatures ranging from 210 to 235° F.

Only hydrothermal systems have shown commercially viable extraction of geothermal energy in the United States and overseas. The most current USGS resource assessment for power production potential predicts that about 9GW is available from 240 recognized hydrothermal systems found in 13 US states (all in the western US, plus Alaska and Hawaii) with 95 percent confidence. The most optimistic resource estimate (5 percent confidence) for these 13 states is 16.5GW.

The USGS technique only takes into account relatively shallow, high-temperature (HT) reservoirs with temperatures more than 150 °C in crustal locations with substantial heat flow. Because the geothermal gradients in the eastern United States are typically lower, HT geothermal reservoirs can only exist at higher depths than in the western United States. West Virginia, for example, has HT sites with above 150 °C rocks at 4.5–5 km deep. Furthermore, low temperature (LT) geothermal resources might be employed for district heating in colder states, a resource potential that is not currently accounted for in USGS geothermal resource estimates.

One of the most difficult issues in using geothermal resources is identifying subterranean sites and depths where geothermal fluids with adequate enthalpy to permit economically effective extraction may be discovered. When relatively shallow reservoirs can support well rates of about 3000 gpm with temperatures high enough for either flash power generators (> 300 °F or 150 °C, so-called HT power plants) or organic Rankine cycle plants (200–300 °F, so-called LT power plants), hydrothermal power plants become a viable option. A recent analysis of the Neil Hot Springs power plant stressed the requirement for well productivity of around 3000 gpm or 100,000 bbls/day as a necessity for electrical power production in such geothermal projects.

6.6.2 Geothermal energy in Texas and other LT geothermal states

Several demonstration projects targeted at harvesting geothermal electricity via coproduction from oil and gas wells have been conducted with DOE sponsorship in Texas, Louisiana, Wyoming, and North Dakota over the last decade. A more recent study of geothermal energy in Texas discovered that the state had little over 1.31024J of geothermal resource accessible, with the majority concentrated around the Gulf Coast. Using the bottomhole temperature of 30,000 wells, a thorough map of the geothermal potential in East Texas was developed by a group of researchers from SMU (Fig. 6.9).

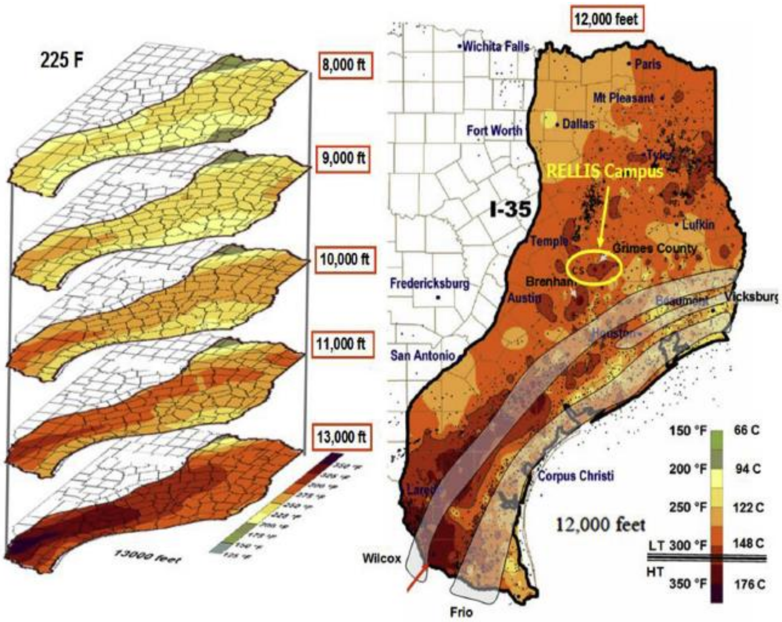


Figure 6. 8. East Texas map *(Ruud Weijermars, 2018)*

According to the heat map generated by, temperatures in Brazos County (home of Texas A&M University) might exceed 300 °F (150 °C) at 12,000 ft deep. The Texas area includes almost 600,000 wells with temperatures ranging from 121 C to 204 C. Statistical approaches have demonstrated that power units might provide between 43,800 MWe and 265,000 MWe power based on the minimum and maximum ratings of a well. The regional potential is then divided into basins, including the Gulf Coast, East Texas, Delaware/Val Verde basins, the Panhandle Anadarko basin, the Trans-Pecos area, and the Maverick basin.

However, most oil and gas wells target Eagle Ford and underlying Austin Chalk strata at vertical depths of 7000 to 9000 ft within certain hydrocarbon maturation periods. The geological landscape of the RELLIS Campus region is rather flat and covered with Quaternary sediments from the Brazos River.

The Texas Rail Road Commission reported 193,807 producing oil wells and 103,526 producing gas wells at the end of 2015. Only since the 1930s have oil and gas production quantities in Texas been consistently tracked, and they have reached astounding levels: 61 billion barrels of oil and 71 trillion cubic feet of natural gas.

6.6.3 China geothermal resources

China has three massive oilfields with prospective geothermal resources: Huabei, Gudong, and Shengli. Among these sectors, Huabei has a successful coproduction plant for electricity generation. The Shengli oilfield has been identified as having the potential to utilize geothermal energy for oil transportation and heating. The geothermal water flooding technology has the potential to boost oil recovery in Gudong, a heavy-oil field. Hot water is reinjected throughout this operation to reduce oil viscosity and increase output. Provide fundamental data, such as reservoir distribution and geothermal gradient, for various additional fields in China in order to enable large-scale geothermal energy development in the near future. The wellhead temperature (WHT) (110 C) and flow rate (33 kg/ s), among other things, are favorable for power generation in the Huabei field, as are a 2349 m-thick carbonate reservoir, dual-porosity, densely located fractures (about 1–2 fractures per square centimetre), a large water flow system available below the oil reservoir, and complete reinjection from the start. Currently, oil output has dropped drastically from 8.1 kg/s to 1.74 kg/s, with the coproduction unit producing 400 kWe gross. The Shengli field, on the other hand, has a lower production temperature, ranging between 60 and 100 degrees Celsius, making it more suitable for direct-use applications. A feasibility assessment for the Gudong oilfield argues that combined electricity production and geothermal water flooding are cost-effective following fresh drillings and well-workover operations. According to this, nine more wells in this 68 km2 area will support an integrated hybrid closed-loop geothermal system with formation temperatures ranging from 48 C to 169 C. The produced electricity may subsequently be sold to the grid for 10 cents per kWh or utilized to boost output from the field's other 21 wells. This study also discovered that in heavy oilfields, the pumping system consumes more than half of the generated electricity.

Country	Oilfield	Cost of Energy (US cents/kWh)
China	-	9,3
Qatar	-	< 5,6
Italy	Villafortuna-Trecato	18,3
USA	Banks field	10,95 - 19,15
	Long Beach	11,0
	Gulf Coast	8,0 - 11,0

Table 6. 1. Geothermal energy price range evaluated in hydrocarbon fields worldwide

6.7 Closed-loop configuration

Figure 6.11 depicts two types of heat exchangers that are often used in a closed-loop system: twin pipe heat exchangers and U-tube heat exchangers. Before filling the abandoned well with materials with suitable thermal qualities, a U-tube heat exchanger must be installed. In actuality, U-tube is more typically used for shallow wells, particularly for space heating and cooling. The existing well outer pipe is utilized as the annulus for double pipe exchangers, while a smaller pipe with insulation is put into the well to form a coaxial double pipe heat exchanger.

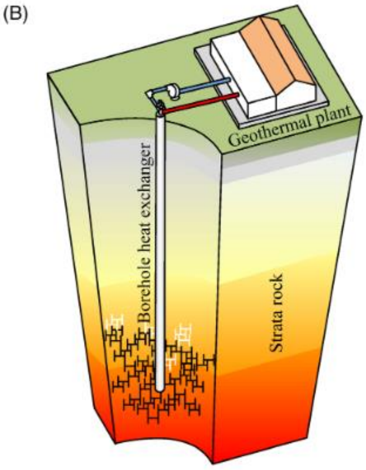


Figure 6. 9. Closed-loop configuration *(Jundika Candra Kurnia, 2020)*

As compared to U-tube, double pipe heat exchanger possesses a larger heat transfer surface area and hence, theoretically a better heat extraction performance For the same injected mass flow rate, due to its larger diameter in the annulus section, it has a lower pressure drop penalty and thus, a lower pumping power. For an abandoned oil well, utilizing a double pipe heat exchanger is considered as a better choice as compared to U-tube heat exchanger. This is due to fact that the existing casing from previous oil and gas extraction can be reused, reducing the cost of installing a new casing or pipes and the overall construction time. The coaxial geometry of double pipe heat exchanger is also more preferable as it offers reduction in thermal resistance between the circulating fluid and the wellbore.

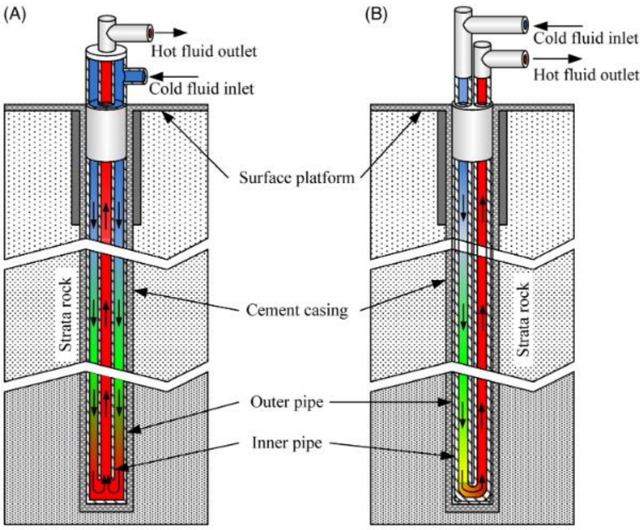


Figure 6. 10. Double pipe (A) and U-tube heat exchanger (B) *(Jundika Candra Kurnia, 2020)*

6.7.1 The single-well (closed loop) concept

Geofluids are cycled in the borehole, where they are not in touch with the surrounding formation, in the single-well (closed loop) models. Despite the substantially lower contact area achieved by fracturing, it is expected that adequate heat may be transported from the formation to the wellbore. The single-well (closed loop) idea, also known as borehole heat exchanger (BHE), can be employed in deep geothermal applications, particularly where access to abandoned "dry" geothermal or hydrocarbon exploration holes is available.

Single-well (closed loop) systems can be utilized for electrical power production, direct use/district heating, or combined heat and power depending on the temperature, heat flux output, and long-term sustainability (CHP). Certain ideas rely on cracks to provide the required contact area for pumped fluids to gain subsurface heat. Deep geothermal technologies have the potential to cause seismicity. The possibility of linked induced seismicity is viewed as a barrier to the continued development of EGS systems that need hydraulic stimulation.

6.7.2 BHE project in Weggis, Switzerland

A BHE project has been running in Weggis, Switzerland, since 1994, with a bottomhole temperature of 78 _C and a depth of 2300m. Figure 6.12 shows a schematic representation of the well. From 1995 to 2000, the single well produced 220 MWh/yr (thermal) for direct heating and heat pump applications, with an average production temperature of 40.5 C and a return temperature of 33.3 C.

Three more multi-family houses were added to the system in 2001. The manufacturing temperature dropped to 37.2 C while the provided heat supply nearly doubled. Furthermore, the top section of the inner pipe of the Weggis deep BHE (0 - 1780 m) is thermally well insulated (with vacuum).

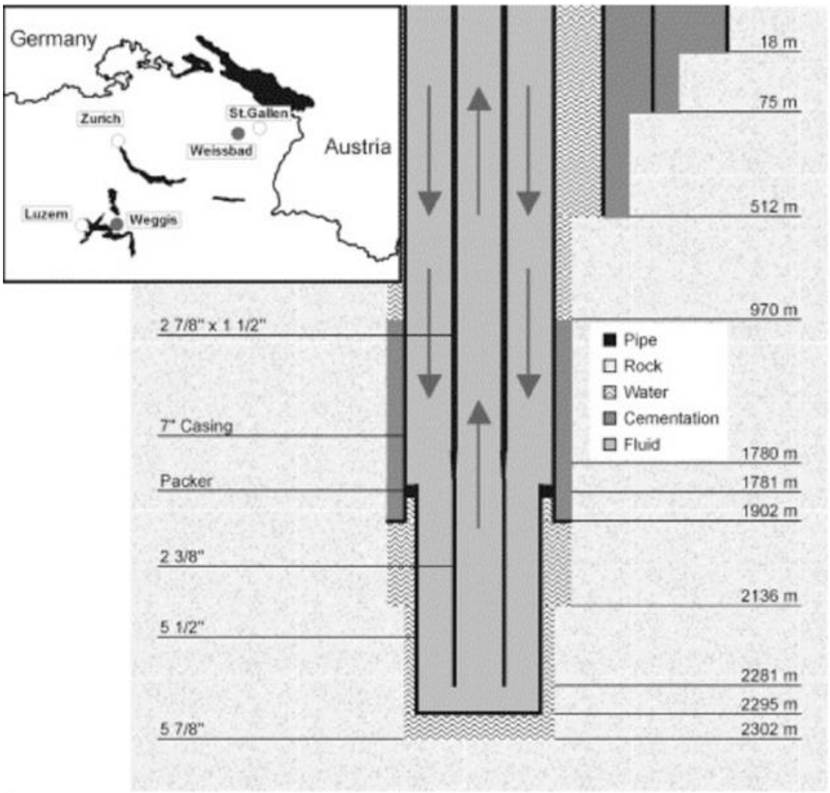


Figure 6. 11. Completion of the deep BHE in Weggis *(Gioia Falcone, 2018)*

6.7.3 The BHE project in Weissbad, Switzerland

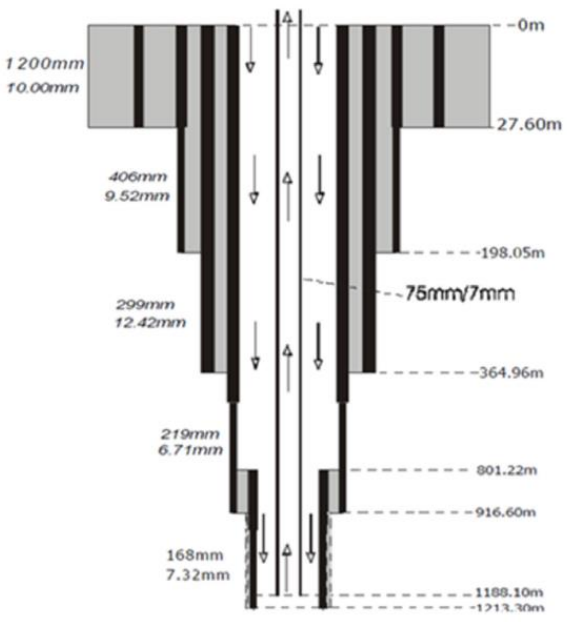


Figure 6. 12. Completion of the BHE in Weissbad *(Gioia Falcone, 2018)*

In 1993, a deep BHE project in Weissbad, Switzerland, re-drilled an old borehole with the goal of locating a porous/fractured aquifer and serving a neighboring spa and hotel complex. Because the further drilling found only tight formations, it was decided to equip the borehole with a deep BHE instead. The well was cemented down to 1213.3 m, when it encountered a downhole temperature of 45 C. (Fig. 6.13). This design was expected to reach an average delivery temperature of roughly 15 C, however the actual operation revealed a yield of just 10.6 C with a water circulation rate of 252m3/d. Based on numerical analysis, it is established that the system's low performance was caused by inadequate casing-formation contact and poor central pipe insulation.

6.8 Utilization of geothermal energy

The total installed capacity for geothermal direct use globally as of the end of 2019 is 107,727 MWt, a 52.0 percent growth over WGC2015, rising at an annual compound rate of 8.7 percent (John W. Lund, 2020). The overall yearly energy consumption is 1,020,887 TJ (283,580 GWh), representing a 72.3 percent increase over WGC2015 and an 11.5 percent compound annual growth rate. The global capacity factor is 0.300 (corresponding to 2628 full load operational hours per year), up from 0.265 in 2015 and 0.28 in 2010, but down from 0.31 in 2005 and 0.40 in 2000. The current greater capacity factor and yearly energy demand growth rate are owing to a rise in geothermal heat pump installations, despite the fact that they have a low capacity factor of 0.245 globally.

Region/Continent (countries/regions)	**MWt**	**TJ/year**	**GWh/year**
Africa (11)	198	3,730	1,036
Americas (17)	23,330	180,414	50,115
Central America and Carribean (5)	9	195	54
North America (4)	22,700	171,510	47,642
South America (8)	621	8,709	2,419
Asia (18)	49,079	545,019	151,394
Commonwealth of Independent States (5)	2,121	15,907	4,419
Europe (34)	32,386	264,843	73,568
Central and Eastern Europe (17)	3,439	28,098	7,805
Western and Northern Europe (17)	28,947	236,745	65,762
Oceania (3)	613	10,974	3,048
Total (88)	107,727	1,020,887	283,580

Table 6. 2. Summary of direct-use data worldwide by region and continent

Geothermal energy, a home source of sustainable and renewable energy, has the potential to replace other kinds of energy consumption, particularly fossil fuels. For many nations, geothermal energy implies less reliance on foreign fuels, and for all countries, it means less pollution from carbon particles and greenhouse gases.

Using 1,020,887 TJ/yr of energy consumed in direct geothermal applications by 2020 (Table 6.2), and assuming that a barrel of fuel oil contains 6.15 x 109 J and is used to generate electricity, the annual savings would be 474 million barrels of oil or 64.4 million tonnes of oil (300 lbs/barrel = 136 kg/barrel = 42 gallons/barrel = 159 L/barrel at density = 0.855 kg The savings would be 237 barrels or 32.2 tonnes if the oil were utilized directly to generate energy by burning it for heating. The real savings will most likely fall somewhere in the middle of these two figures. Take note that 474 million barrels equals around 1.6 days of global oil use.

Compared to utilizing electricity, the carbon savings from natural gas would be 20.32 tonnes/TJ, 86.81 tonnes/TJ from oil, or 100.82 tonnes/TJ from coal, for a total carbon production savings of 14.81, 63.38, or 73,62 million tonnes, respectively. Similarly, considering carbon dioxide emissions of 193 kg/MWh (53.6 tonnes/TJ), 817 kg/MWh (227.0 tonnes/TJ), and 953 kg/MWh (264.7 tonnes/TJ) while producing electricity from natural gas, oil, and coal, the reductions in CO2 emissions would be 54.27, 229.88, and 268.07 million tonnes, respectively.

Conclusion

A sedimentary basin is a section of the Earth's crust covered by a thick series of sedimentary rocks. Hydrocarbons are generally found in sedimentary basins, one of the pillars of the sedimentary organic hypothesis for the genesis of hydrocarbons is this essential reality. Considering the temperature ranges associated with wells in hydrocarbon fields, the energy production based on the exploitation of the available profound geothermal energy associated with disused hydrocarbon wells could represent a considerable future energy solution. It could solve problems related to suspended oil and gas wells near municipalities, allowing us to hypothesize long-term scenarios for oilfields exploitation. Currently, the use of oil and gas wells for this purpose is more expedient and less expensive, as the cost of investment in wells drilled for geothermal energy is quite high.

A comprehensive analysis of the world's largest petroleum basins was presented in the first part of this research. In the second part, descriptions of drilling techniques for hydrocarbons extraction and decommissioning processes of oil and gas structures in Oilfields were proposed. Conventional and unconventional approaches for the geothermal exploitation methods and the design of deep geothermal wells in oilfields were described in the last part the the thesis project. The analysis covered injection-production well doublets, open-loop single wells, U-tube and Coxial single wells (BHEs), among other single well configurations.

Various approaches for deep geothermal energy utilization have been presented in the literature, some of which were inspired by the necessity to devise methods appropriate for circumstances where the heat is available but the formation's permeability and/or porosity are not. The BHE concept, which was initially developed for shallow geothermal applications, has the potential to be applied, at least in theory, to greater depths. To this day, there have only been a handful of deep installations carried out, and those that have been done so have met with varying degrees of success. The latter has been the focus of published patents proposing modifications to the original BHE principle. These modifications include enlarging the downhole contact area between formation and well and adding fillers to enhance the heat transfer between the near-wellbore region and the fluid circulating in the well. Both of these modifications have been proposed as potential improvements. It is typical for the majority of these proposed BHE modifications for deep applications to lack the comprehensive studies necessary to predict their thermal sustainability.

It consists in performing operations at the expense of lower costs for the economic efficiency of obtaining geothermal energy in the methods we are looking at. As a result, it is possible to reduce the costs of re-drilling abandoned oil and gas wells, as well as develop various application methods in the inspection mode on sedimentary basins with high temperatures at shallow depths.

The results of the numerical simulations of BHE designs performed over the years indicate that additional research into engineered, closed-loop single-well solutions is required in order to fully realize the enormous potential of deep geothermal resources located all over the world. These geothermal closed-types of solutions could initially be applied to particularly favorable candidate locations, such as shallower (but high temperature) settings, such as those encountered in Iceland, for example, and/or where abandoned or "dry" geothermal or hydrocarbon wells can be re-used, in order to minimize operational costs while gaining valuable implementation lessons.

The US by far the biggest geothermal energy producer in the world. At the moment, all of the geothermal power plants in the United States are in a few western states. These states have crustal areas with strong local heat flow, which, when combined with local hydrothermal reservoirs, makes it easy to get heat out of the ground. Wells in the Lightning Dock area get their water from a hot plume reservoir that is 350 to 600 feet deep and is usually between 210 and 235° F. With 95 percent certainty, the most recent USGS assessment of the power-producing potential of 240 known hydrothermal systems in 13 US states says that about 9GW of power could be made from them. The most optimistic estimate (50% confidence) for these 13 states is that they have 16.5GW of resources.

The USGS method only looks at relatively shallow, high-temperature (HT) reservoirs with temperatures above 150 °C in places in the crust where there is a lot of heat flow. Geothermal gradients are usually lower in the eastern U.S., so HT geothermal reservoirs can only be found at deeper depths than in the western U.S. For example, HT sites in West Virginia have rocks that are hotter than 150°C and are 4.5–5 km deep. Furthermore, in colder states, low-temperature (LT) geothermal resources can be used for district heating, a resource potential not currently included in USGS geothermal resource estimates. When relatively shallow reservoirs can support well rates of about 3000 gpm at temperatures high enough for either flash power generators more than 300 °F or 150 °C, so-called HT power plants, or organic Rankine cycle plants about 200–300 °F, so-called LT power plants, hydrothermal power plants become a viable option. At 12,000 feet deep, the temperature in Brazos County, which is in Texas, could be more than 300 °F (150 °C). Nearly 600,000 wells in the Texas area have temperatures between 121 C and 204 C. Depending on the minimum and maximum ratings of a well, the power units could provide between 43,800 MWe and 265,000 MWe of power.

Depleted oil wells in the United States can be used to generate geothermal energy for heating and cooling without the need for additional drilling. The new RELLIS community's proximity to geothermal energy resource infrastructure provides a significant cost advantage, which increases the potential economic potential for an EGS-powered space air conditioning system. The reserve reservoir(s) will be used to economically optimize the heating strategies by using various types of fluid circulation models. The reservoir models can be used to determine the best potential process, such as the conditioning of production brine and the conversion of produced hot water to energy. The most cost-effective way to meet the cooling and heating needs of the RELLIS campus from brine will be determined by evaluating a cascaded combination of heating, cooling, and dehumidification technologies.

Further development and analysis of the various hydrocarbon fields located in areas with higher potential geothermal resources could make it easier to find a number of abandoned wells. This would make it possible to explore and extract the geothermal resources that have been found. Taking all of the above information into account, it's easy to see how getting geothermal energy from places where oil and gas are found could be an interesting topic for discussions and more research.

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