

A photograph of an industrial refinery at night. Several tall, cylindrical distillation columns are illuminated by warm lights, creating a golden glow. The sky is a deep blue, and a full moon is visible in the upper center. The image is framed by a dark blue background with a yellow diagonal stripe.

Introduction to Oil and Gas Industry

Upstream Midstream Downstream

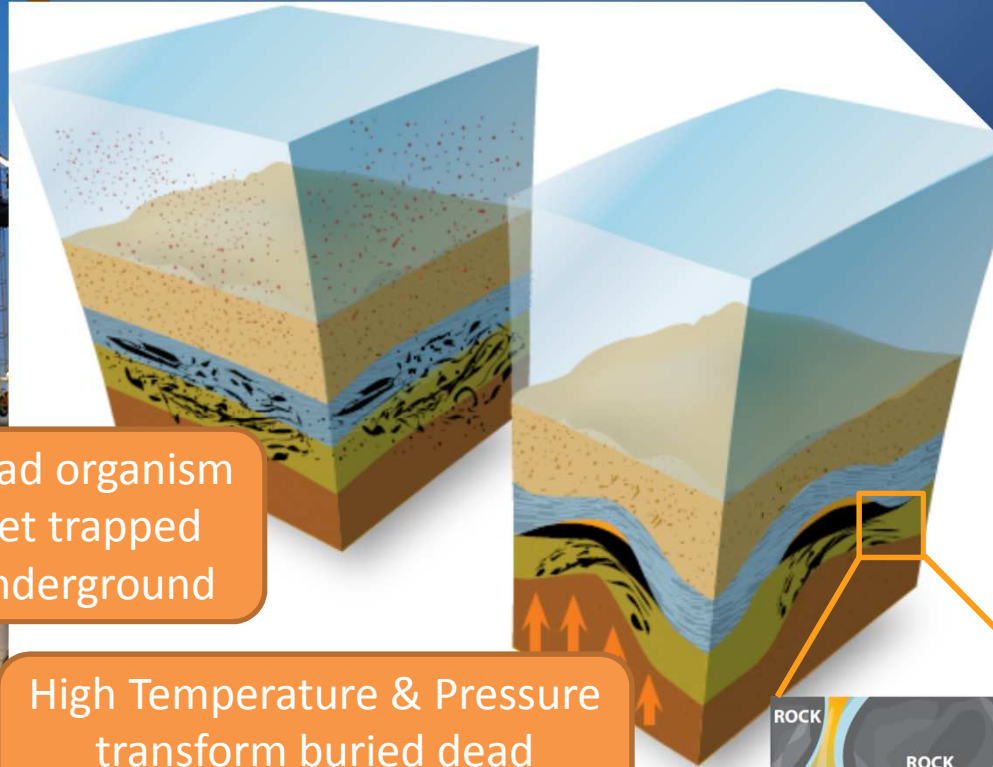
By Puput Aryanto Risanto
rev.1 17 January 2017

Oil & Gas in Our Life

- Transportation Fuel (gasoline, diesel fuel, jet/aviation fuel, marine fuel oil/MFO, natural gas vehicle/NGV, high speed diesel/HSD)
- Power Plant Fuel (natural gas, compressed natural gas/CNG, diesel fuel)
- Household Fuel (heating oil, liquefied petroleum gas/LPG, kerosene)
- Petrochemical Products (plastic, fertilizer, synthetic fiber, synthetic rubber, insecticides, pharmaceuticals, detergent, paints, creams, solvent, industrial chemical, industrial gas, etc)
- Asphalt / bitumen



Oil & Gas Formation



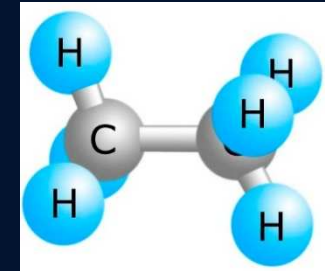
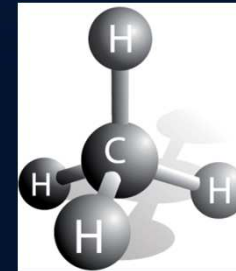
Dead organism
get trapped
underground

High Temperature & Pressure
transform buried dead
organism into oil & gas

Oil & gas is also called **PETROLEUM**
which means "Rock Oil" in Latin word



- It is formed from the accumulation of decomposition of plants and marine animals which died million years ago and trapped beneath the ground under high pressure and temperatures.
- Oil & gas compound consist of Carbon & Hydrogen Atom, that's why it is called HYDROCARBON.
- Crude Oil is liquid while Natural Gas is gaseous hydrocarbon at room temperature.



Oil & Gas Early History



Eternal flame at
Ateghash Fire Temple,
Baku Azerbaijan

- Oil & gas had been used for centuries like ancient peoples worshipped sacred fires (eternal flame) fuelled by natural gas seeping to the surface through pores and cracks.
- About 6000 BC, thick gummy asphalt was used to waterproof boats and heat homes.
- About 3000 BC, the Egyptians used asphalt in the construction of the pyramids, to grease axles of the Pharaoh's chariots, and as an embalming agent for mummies & medicines.
- When whale oil (extracted from whale fat), the main source of lamp fuel in early 1980, became scarce, a new source is introduced by distilling natural petroleum seeps and coal into lamp oil / kerosene.



Birth of Modern Oil & Gas Industry



Drake Well

- First refinery begun in 1846 when Abraham Gessner of Nova Scotia, Canada, invented a process to produce kerosene for lamp from coal.
- In 1858, James Miller Williams, a 39 year old carriage maker from Ontario, Canada, made the first major commercial oil discovery in North America at Oil Springs, Ontario, Canada.
- He struck oil at a depth of only 18 m by drilling in "gum beds" in Lambton County, 25 km southeast of Sarnia. Williams refined the oil he produced and sold the product as lamp oil.
- In 1859, Colonel Edwin L. Drake discovered oil in Titusville, Pennsylvania by drilling to 21 m. This discovery marked the birth of the modern petroleum industry in the United States.
- The invention of the gasoline engine (1885) and diesel engine (1892) boosted the refineries industry to produce gasoline and diesel fuel.

Oil & Gas Industry Characteristics



- Large investment, can reach billion of US\$.
- High risk in all aspects (people safety, environment, investment, reputation).
- High reward/return.
- Long term business from initial investment until revenue generated, even longer until break even point (can be more than 20 years).
- Complex operation, involves multi discipline experts from both technical and non-technical.
- Strategic value (economic & politic).
- Global impact.



Oil & Gas Industry Sector

Upstream

Finding, lifting, and processing oil & gas from subsurface into surface and ready for transportation. Also known as Exploration and Production (E&P).



Midstream

Transportation and storage of crude oil and natural gas from E&P plant for further processing by pipeline, railway, road, or tanker.



Downstream

Further processing of crude oil and natural gas into useful final product or raw material for other industry. Also known as Refining & Marketing (R&M)





UPSTREAM

Upstream Oil & Gas Life Cycle

Licensing

Contract signing

- Activities to offer the right to manage an area (block) which is expected to contain oil & gas

Exploration

Discovery

- Activities to search for oil & gas deposits on the reservoir beneath the earth surface within block's boundary

Appraisal

Project Sanction

- Activities to define the oil & gas volume and characteristic more precisely after discovery

Development

First oil/gas

- Activities to build the subsurface & surface facilities to produce oil & gas safely & efficiently

Production

End of Production

- Activities to extract, process, and export oil & gas as per contract agreement

Abandonment

Contract expiry

- Activities to plug wells permanently, remove surface facilities, and restore the block as per initial state



Licensing Round

- Government has the area (including oil & gas beneath the surface) but no resource (money, man power, technology), while Oil Company have the resource, but not the area.
- Government, via host authority (government regulatory body or national oil company) will offer certain area known as “block” to oil companies in an activity called “**Licensing Round.**”
- Government will offer raw data & petroleum agreement to attract oil companies to invest for exploration & production (E&P) activities.
- Oil companies will compete each other in a bidding / tender stage to obtain the right for E&P in a certain block. The winner will be granted the right (contract) to manage E&P activities in a certain period and get compensation based on the agreement.
- In this stage, government need to attract investment by offering “interesting package” while keep protecting the national interest.

Exploration & Appraisal

Exploration

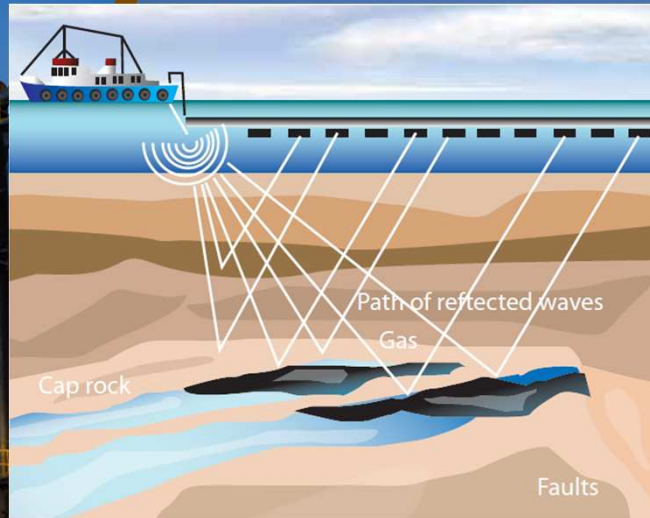
- Activities to find oil & gas prospect beneath the earth surface by means of gravity survey, magnetic survey, and seismic reflection survey.
- Once prospect is likely to be found, exploration (wildcat) drilling will be conducted to determine the presence of oil & gas reserve.
- Most wildcat drilling fail to find oil & gas (dry hole), only few (less than 25%) hits oil & gas layer (discovery).
- After discovery, more drilling is required to “appraise” the reservoir.

Appraisal

- It is required to determine the reservoir size which define the volume & to get better characteristic of oil & gas.
- Volume will be measured in million barrels (MMbbls) oil and billion cubic feet (Bcf) gas, both original in place volume (Oil Initial In Place / OIIP and Gas Initial In Place / GIIP) & recoverable volume.
- Important characteristic includes pressure, temperature, oil viscosity, hydrocarbon composition, compartmentalization, and contaminants.



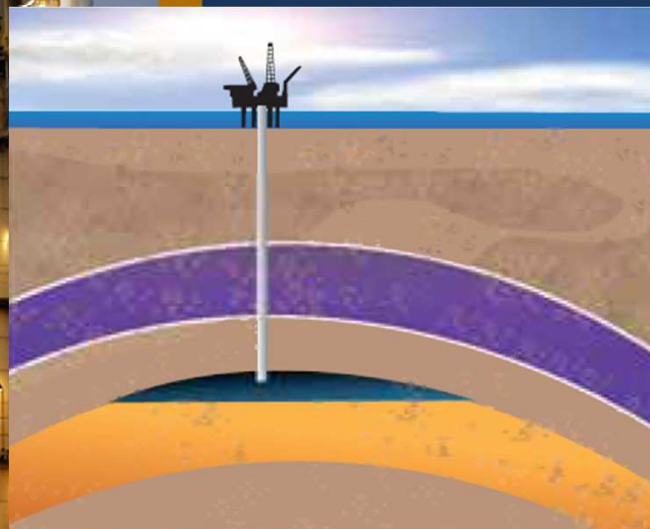
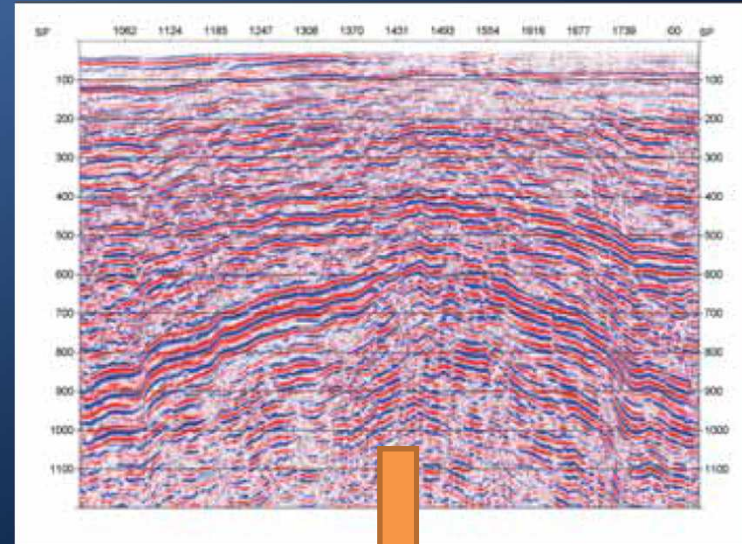
Seismic & Drilling



1. Seismic



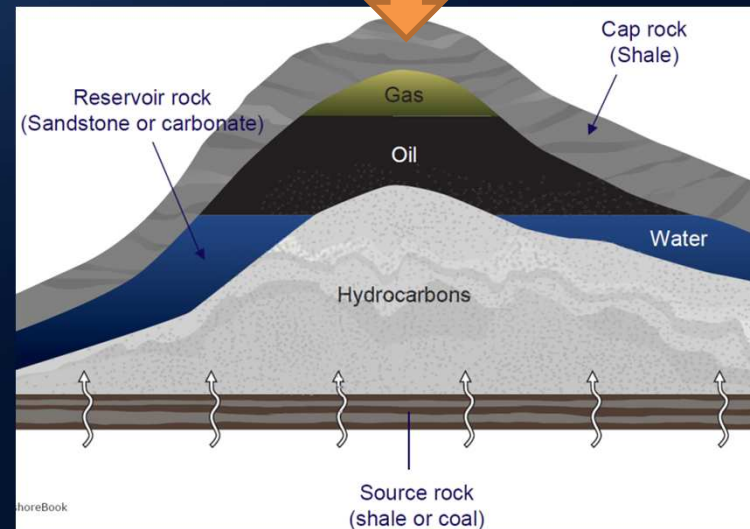
2. Seismic
2D imaging



3. Further
modelling



4. Drilling



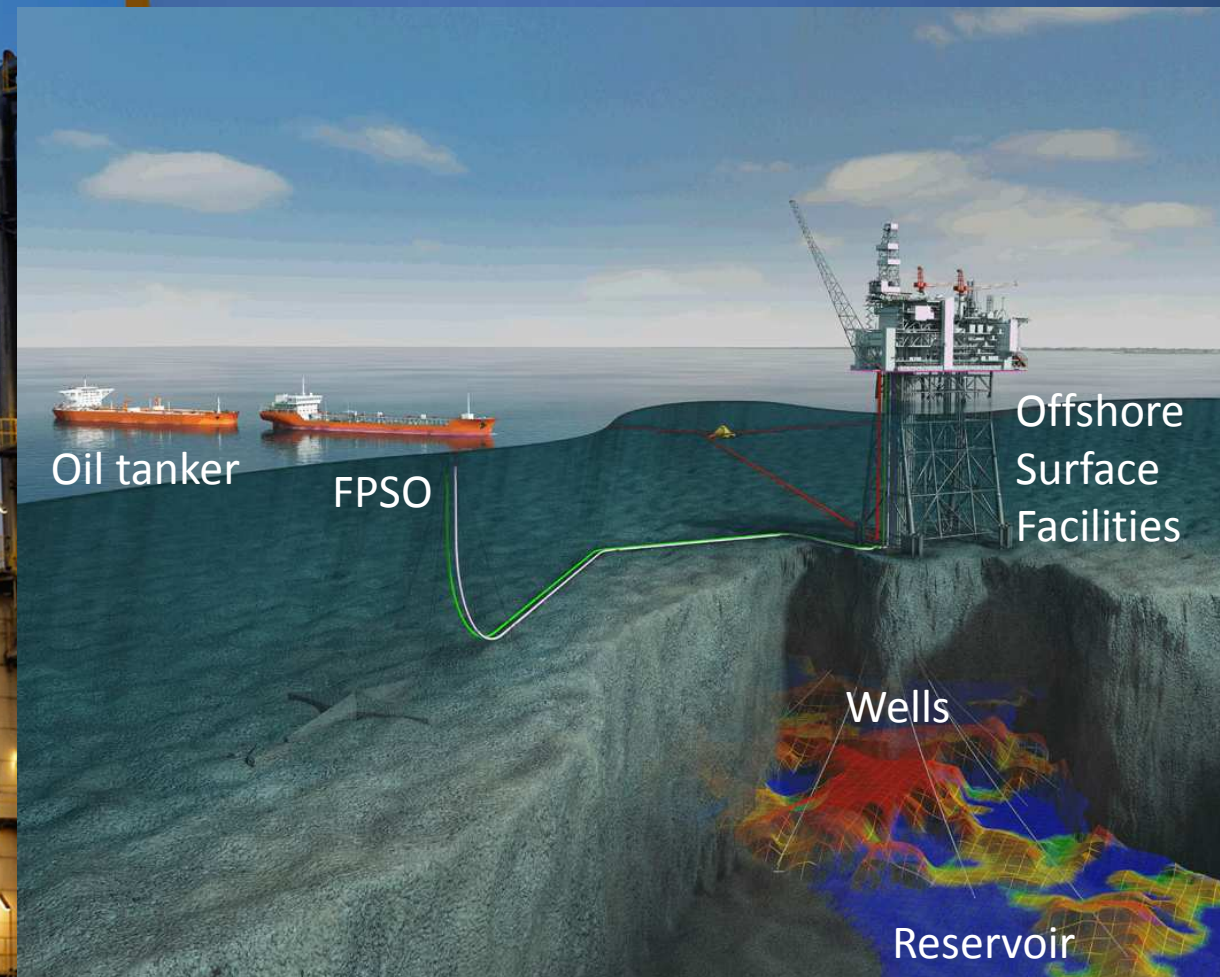
Reserve Type

- Once appraisal conducted, it will determine the quantity of petroleum which can be recovered / produced. Typically, only 30% of oil and 70% of gas can be recovered, can be more if advance technique applied like water injection & submersible pump.
- **Proved (1P)** : Quantities of oil and gas, which, by analysis of geoscience and engineering data, can be estimated with reasonable certainty to be economically producible—from a given date forward, from known reservoirs, and under existing economic conditions, operating methods, and government regulations. At least 90% probability (P90) that the quantities actually recovered will be equal or exceed the estimate.
- **Unproved** : Reserves are based on technical data similar to that used in estimates of proved reserves; but technical, contractual, economic, or regulatory uncertainties preclude such reserves being classified as proved. Unproved reserves may be further classified as probable reserves and possible reserves.
 - **Possible (2P)** : Unproved reserves which analysis of technical data suggests are more likely than not to be recoverable. At least a 50% probability (P50) that the quantities actually recovered will equal or exceed the sum of estimated proved plus probable reserves.
 - **Probable (3P)** : Unproved reserve which analysis of technical data suggests are less likely to be recoverable than probable reserves. At least a 10% probability (P10) that the quantities actually recovered will equal or exceed the sum of estimated proved plus probable plus possible reserves.

Field Development Plan (FDP)

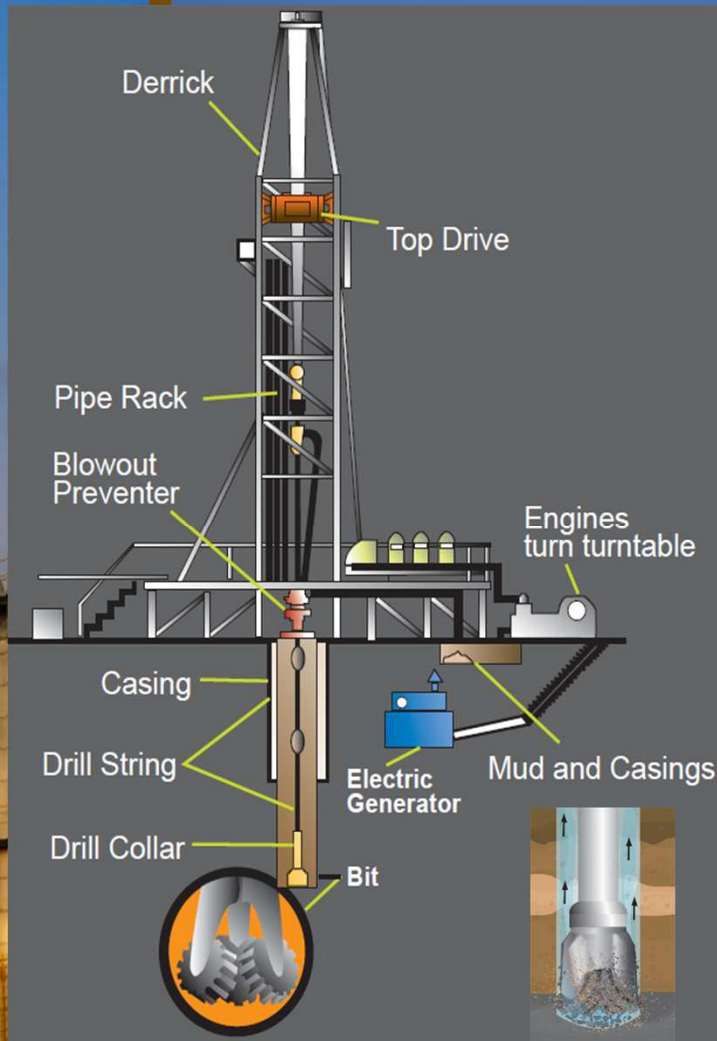
- Once the estimated recoverable value is determined, the Company will prepare a plan to monetize the reserve, called Field Development Plan / Plan of Development (PoD).
- FDP shall contain at least :
 - Subsurface characteristic (OIIP, GIIP, contaminants, etc)
 - Recoverable reserve in P90-P50-P10
 - Production Rate & Field Life
 - Production Facilities (number & type of wells, surface facilities type)
 - Project Plan (including Cost, Schedule, Quality)
 - Project Economics
 - Other aspects like Risk, Health Safety Environment (HSE)
- FDP shall be approved by the host authority. Once approved, the Company will conduct a tender for facilities development.
- In the same time, Company will secure the hydrocarbon sales, especially gas, known as Gas Sales Agreement (GSA). While for oil, it will be absorbed by the market as per oil price trend.
- Once the GSA secured and cost of development known from proposed tender price, the Company will further calculate the project economic. If it meet the criteria, the Company will sanction (commit to invest money) the project, known as Final Investment Decision (FID)

Production Facilities

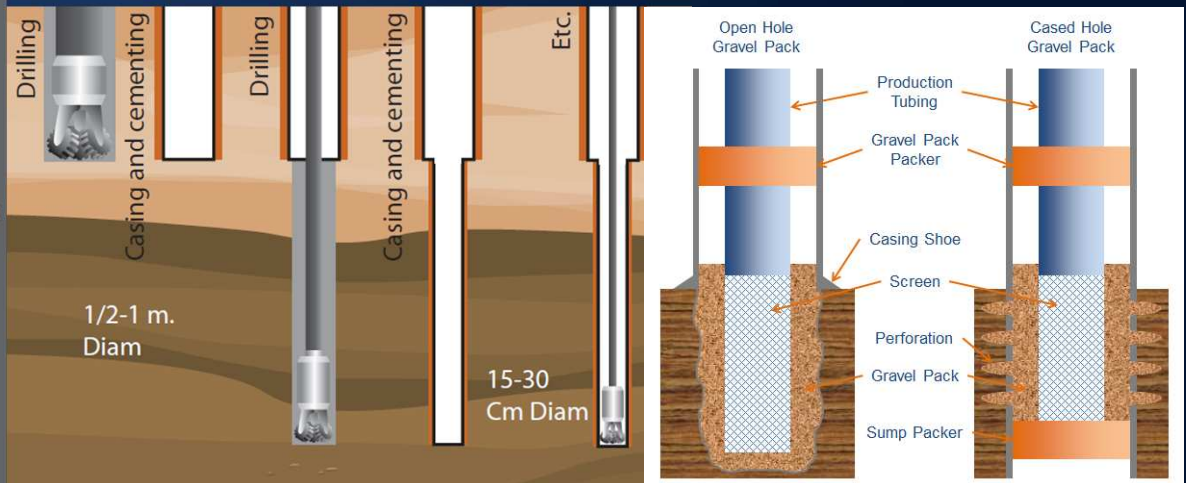


- A set of equipment to extract (lift) oil & gas from subsurface to surface, process, & export it to customer as per requirement specified in the contract.
- Based on the location, it consists of subsurface (wells) & surface facilities.
- Optimum facilities size will depend on reservoir size & contract duration which will define the optimum production rate

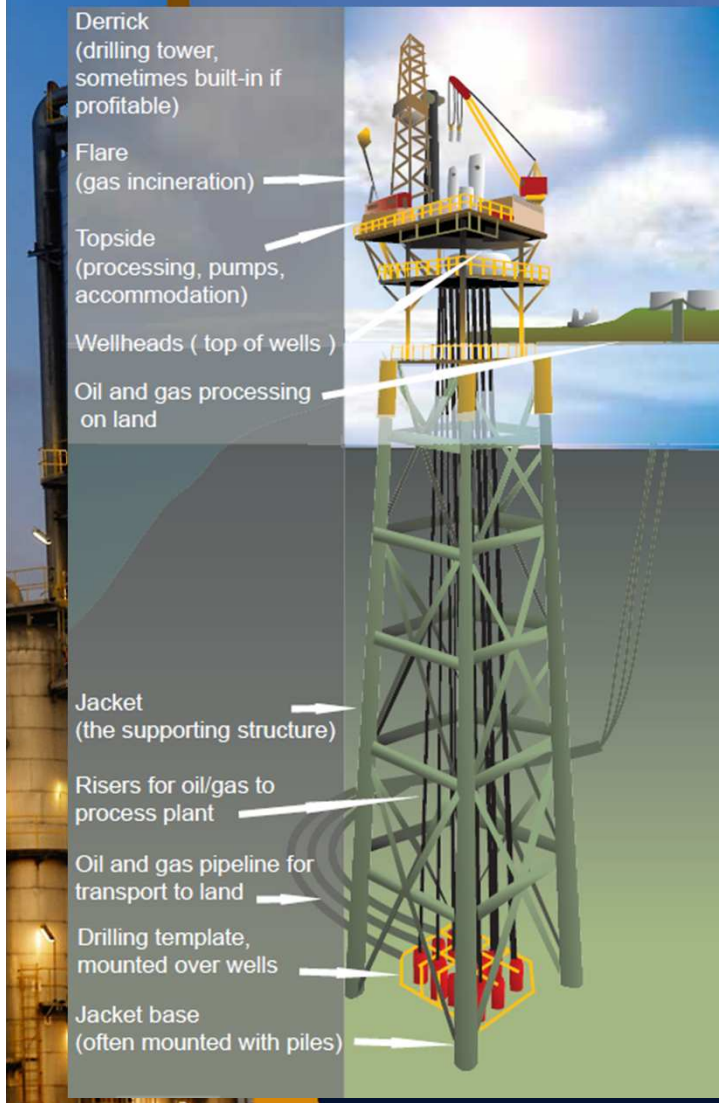
Drilling & Completion (Wells)



- A well is created by drilling a hole into the earth by using a drilling rig that rotates a drill bit.
- Once drilled, a steel pipe called casing is placed in the hole & secured with cement. This process is continued by using smaller drill bit & casing until reach the reservoir target.
- After reaching the target, well must be “completed”. The process to prepare the well to produce oil & gas is called “completion”.
- Completion is designed to allow oil & gas to flow but to block unwanted material like sand.



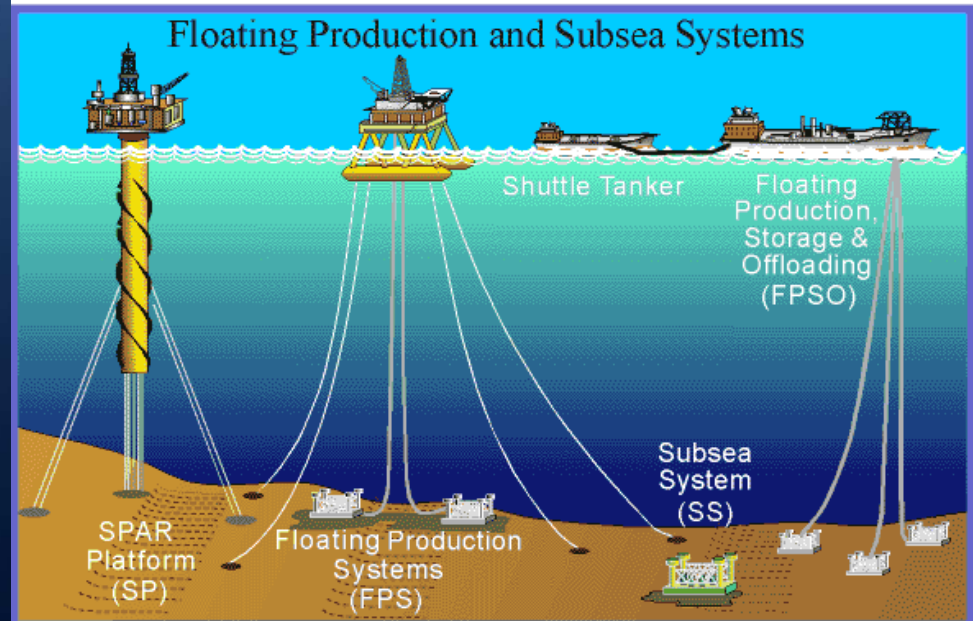
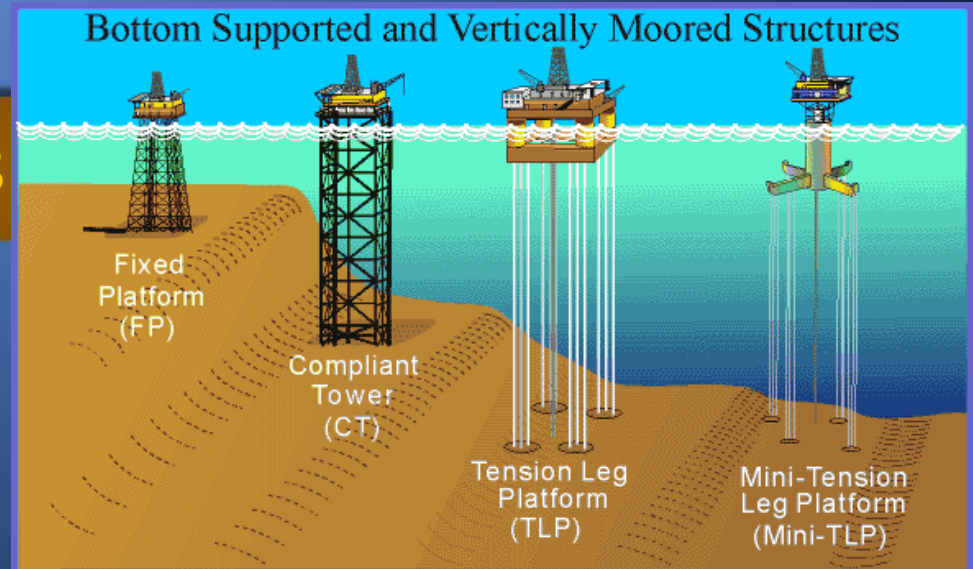
Surface Production Facilities



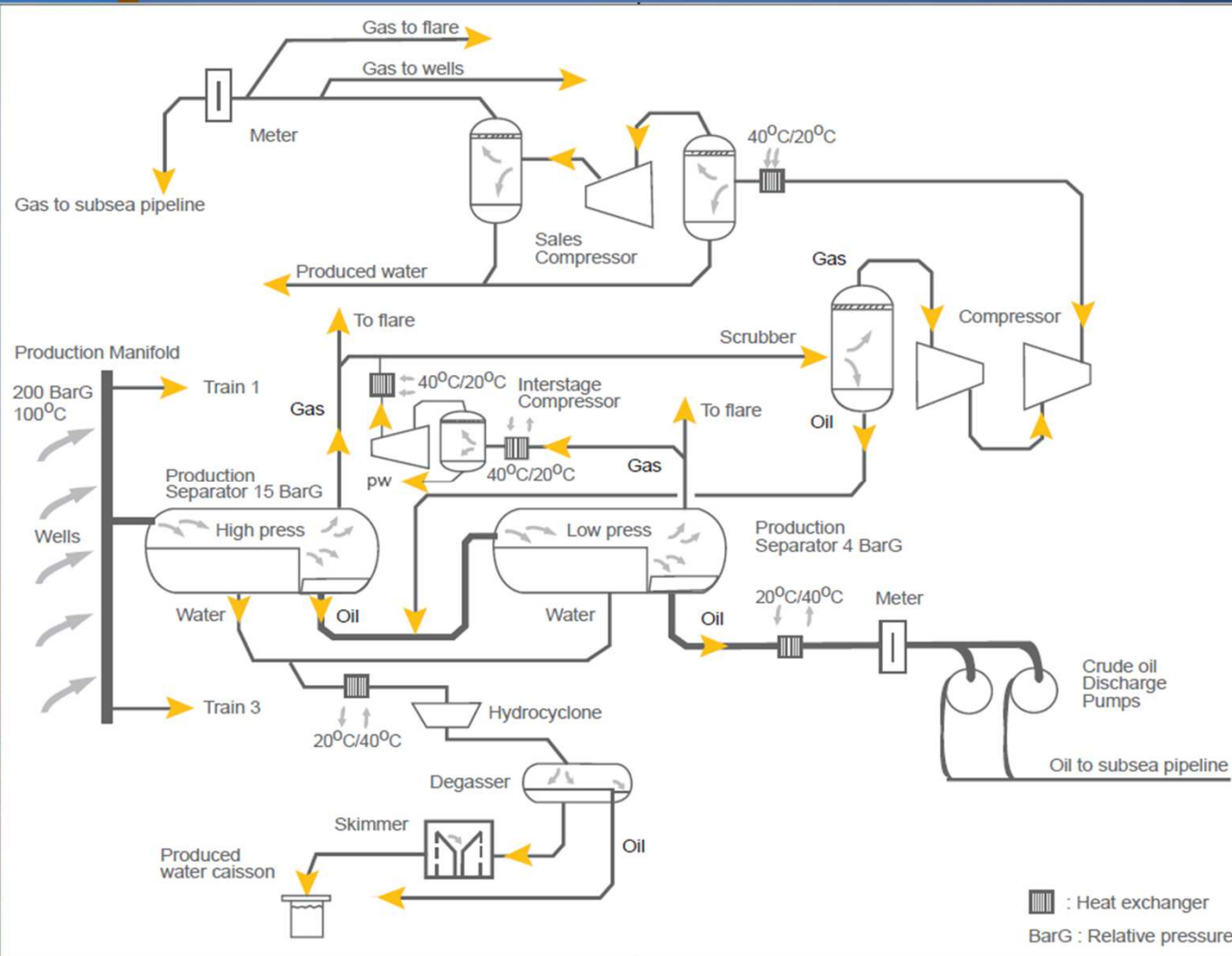
- Surface Facilities consist of wellhead, processing, and exporting facilities.
- Wellhead is the top part of the wells which is used to control the flow, protect from excessive pressure, and interface between surface and reservoir.
- Main processing function is to separate the mixture of oil, gas, water, and other contaminants (i.e. CO_2 , H_2S) and to condition the crude oil and natural gas as per required sales specification.
- Once crude oil processed, it will be exported through pipeline, oil tanker, truck, or railway.
- For natural gas, it can only be exported by pipeline. If the volume is too big or the distance is too far, gas has to be liquefied and exported in liquid phase by LNG tanker.
- Based on the location, it can be placed on land (onshore) or sea (offshore).

Offshore Facilities

- Based on the substructure (the structure which supports the equipment above called topside), offshore facilities is divided into :
 - Bottom Supported & Vertically Moored
 - Floating & Subsea

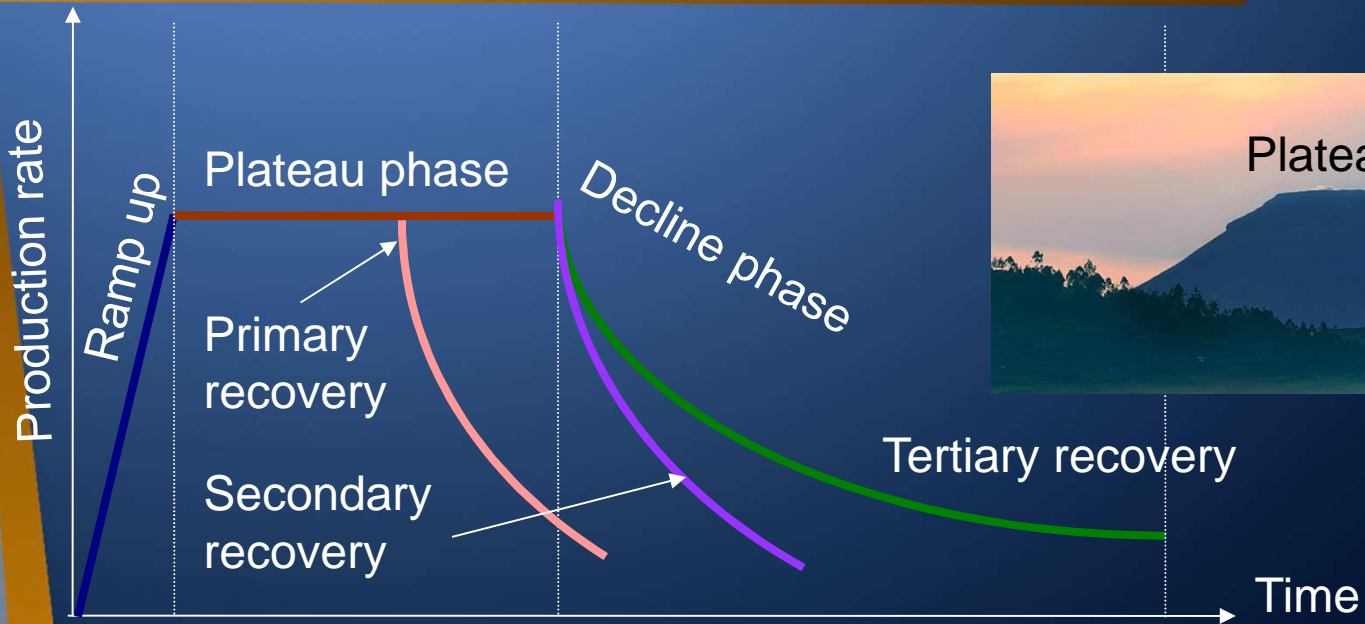


Oil & Gas Processing Facilities



- Oil-gas-water mixture is separated in separator.
- Oil will be stabilized by removing more gas, then pumped to pipeline or FPSO.
- Gas will be treated to remove more liquid, then compressed to pipeline.
- Water will be treated before disposed overboard / re-injected into reservoir.

Production Period



- Typical production phase start with ramp up period (increase production rate up to peak, normally less than a year), then plateau (maintain peak for several years, for oil production normally less than 5 years while for gas production between 5 to 10 years), then declining until reach economic limit (timing when operating cost is higher than production revenue) or end of contractual period.
- Plateau & decline phase can be extended by applying secondary recovery (i.e. gas injection & water injection) and tertiary recovery (i.e. chemical injection & steam injection), however cost to benefit ratio must be carefully calculated since secondary/tertiary recovery is more expensive than primary recovery.

Abandonment



Special vessel to remove offshore platform

- The last phase in upstream life cycle is abandonment.
- The activities comprises well plug & abandonment (P&A) and surface facilities removal.
- Well must be permanently closed and sealed, so no more hydrocarbon can escape to the surface.
- Surface facilities must be removed until few meter below seabed, or left on the seabed as an artificial reef after free hydrocarbon condition reached.
- Site must be restore to as close as its original condition.

A photograph of an industrial refinery at night, featuring several tall, cylindrical distillation columns with complex piping and ladders. The scene is illuminated by artificial lights, and a large, bright full moon is visible in the dark sky. The image has a dark, monochromatic color palette with a reddish-brown tint.

MIDSTREAM

Oil Transportation - Onshore



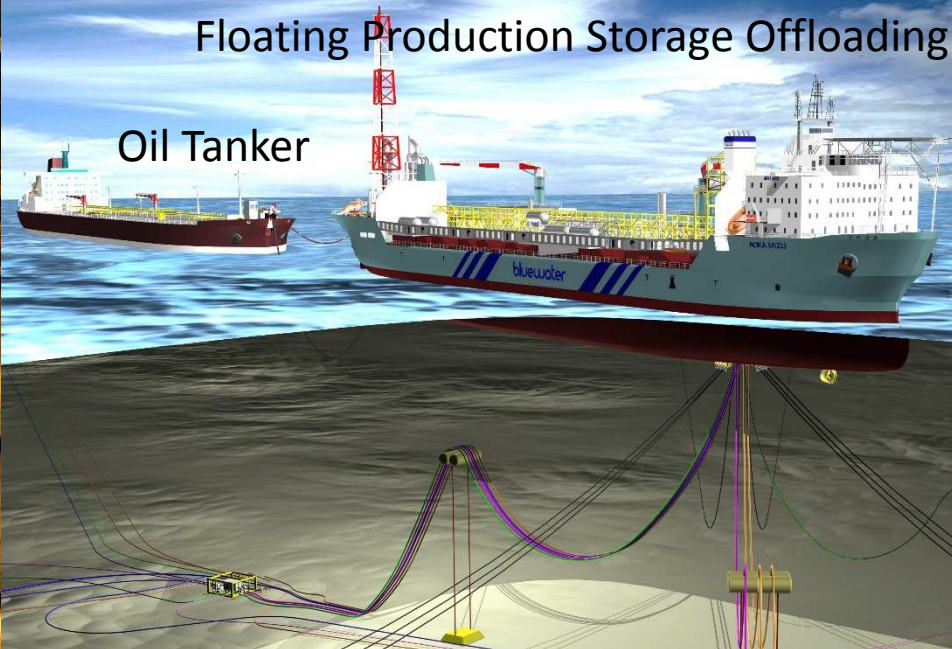
- Since most of the oil & gas field is located far from the civilization, it is crucial to deliver the crude oil & natural gas to increase its value.
- Initially, produced oil is stored inside wooden barrel which then delivered by using horse carriage. It is the beginning of using “barrel” as oil volume measurement unit.
- 1 barrel = 42 US gallon = 159 liter.
- After invention of gasoline & diesel engine, horse carriage is replaced by truck & train.
- Once the volume getting bigger and the distance getting further, barrel method become uneconomic and pipeline was introduced.
- Pipeline is a long connected pipe to transfer liquid/gas. Pipeline characteristic is mainly defined by diameter, length, material, and thickness.

Oil Transportation - Offshore

- Normally, offshore pipeline laid on the seabed used to convey oil from offshore platform to onshore facility.
- However, if the distance is too far or the volume is too low, transporting liquid via pipeline can be technically and economically challenging.
- In this case, oil will be stored offshore (by using FPSO, FSO, or subsea storage) and then transported by using oil tanker.

Floating Production Storage Offloading

Oil Tanker



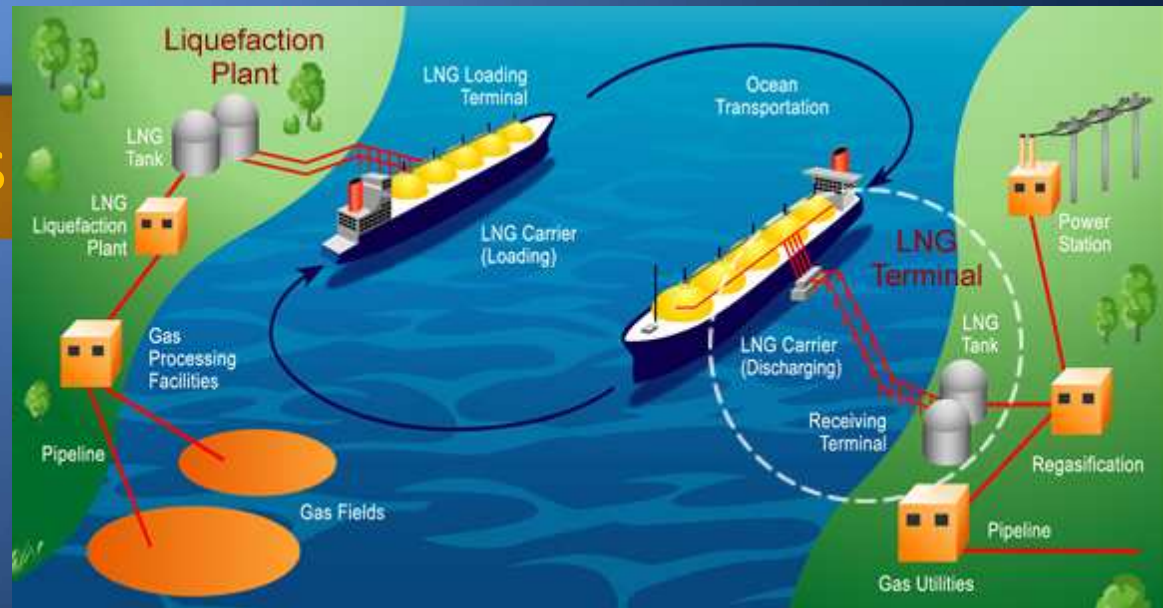
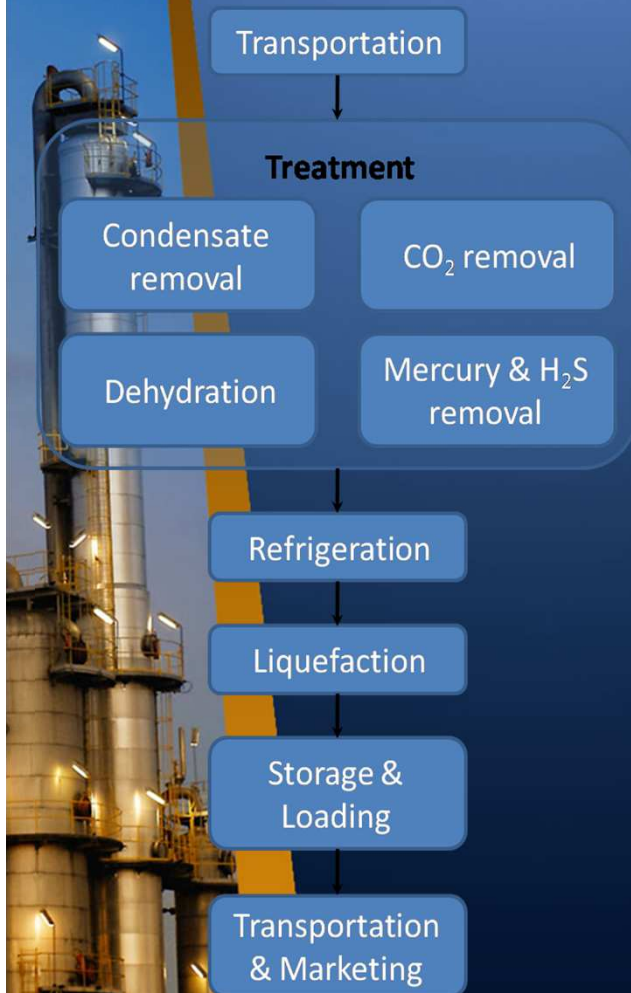
Subsea Storage



Gas Transportation

- Initially, gas is considered by-product which is only disposed by burning or commonly known as flaring.
- Only after gas can be monetized / sold (petrochemical plant, power plant), gas transportation is required.
- Since natural gas cannot be stored easily like liquid, produced gas has to be delivered soon after processed by using pipeline, either onshore or offshore.
- However, if the distance is too far and the volume is too big, pipeline become un-economical.
- In this case, gas has to be transformed into liquid phase by condensing it up to -162°C in atmospheric temperature to reduce its volume by 600 times, which is known as Liquefied Natural Gas (LNG).
- LNG can be transported in a specially designed cryogenic (very cool) tank attached to vessel (known as LNG tanker) or truck.

LNG process



- First LNG plant was built in Ohio, US, on 1940.
- LNG plant is very large and complex, hence initially it has to be built onshore.
- First, gas has to be purified to contain only methane (CH₄) & ethane (C₂H₆) since other material will freeze & block liquefaction process.
- Then, gas is cooled down by using cooler liquid known as refrigerant. To achieve very low temperature, cooling is done in several stage until gas liquefied.
- LNG is stored in a tank and ready for transportation.
- After delivered to receiving facility, LNG is transformed into gas again, known as regasification process.

Floating LNG (FLNG)

- If large gas field is located very far from shore, transporting large quantity of gas via pipeline is technically & economically challenging.
- Small & medium size gas field located far from shore sometimes cannot justify the large investment to built LNG plant onshore.
- Another problem with onshore LNG is land acquisition.
- Long research had been conducted to bring LNG process and export facility into a floating platform.
- First Floating LNG project sanctioned is Shell Prelude on May 2015. It is located on Browse Basin, 475 km from Broome, Western Australia.



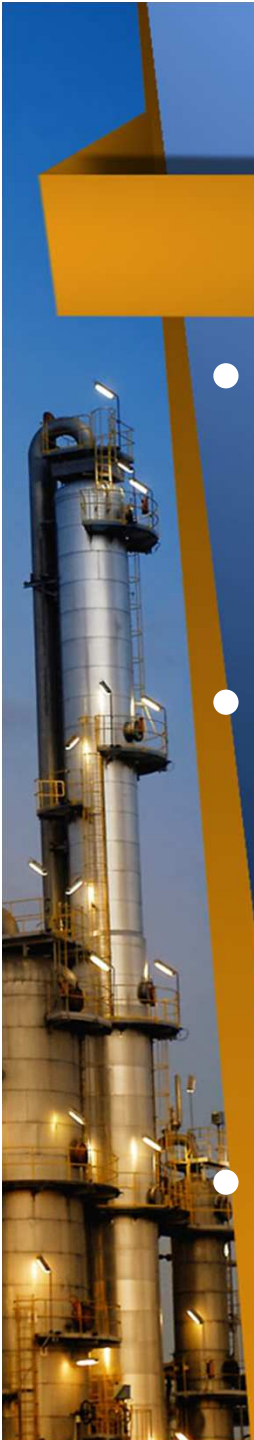
3D image of Shell Prelude FLNG with LNG tanker along side. The FLNG size is approximately 4 times football field, make it the largest vessel ever built so far.

A photograph of an industrial distillation plant at night. Several tall, cylindrical distillation columns are visible, illuminated by small lights. A large, full moon is in the dark sky. The image has a dark, reddish-brown color cast. A semi-transparent dark box is overlaid on the right side of the image.

DOWNSTREAM

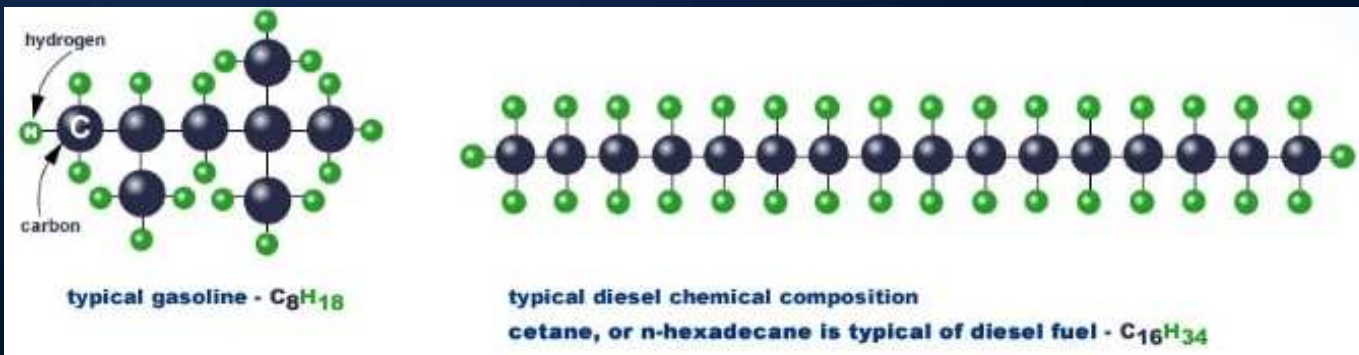
Downstream Industry

- A portion of the industry that is responsible for the refining, distributing, and retail of petroleum products, sometimes also called Refining & Marketing (R&M).
- Refining means process the raw materials (crude oil & natural gas) into higher value product, either final product (ready to consume like LPG for home cooking) or intermediate product (raw material for further processing like ammonia for fertilizer).
- Downstream plants include oil refineries and petrochemical plants.

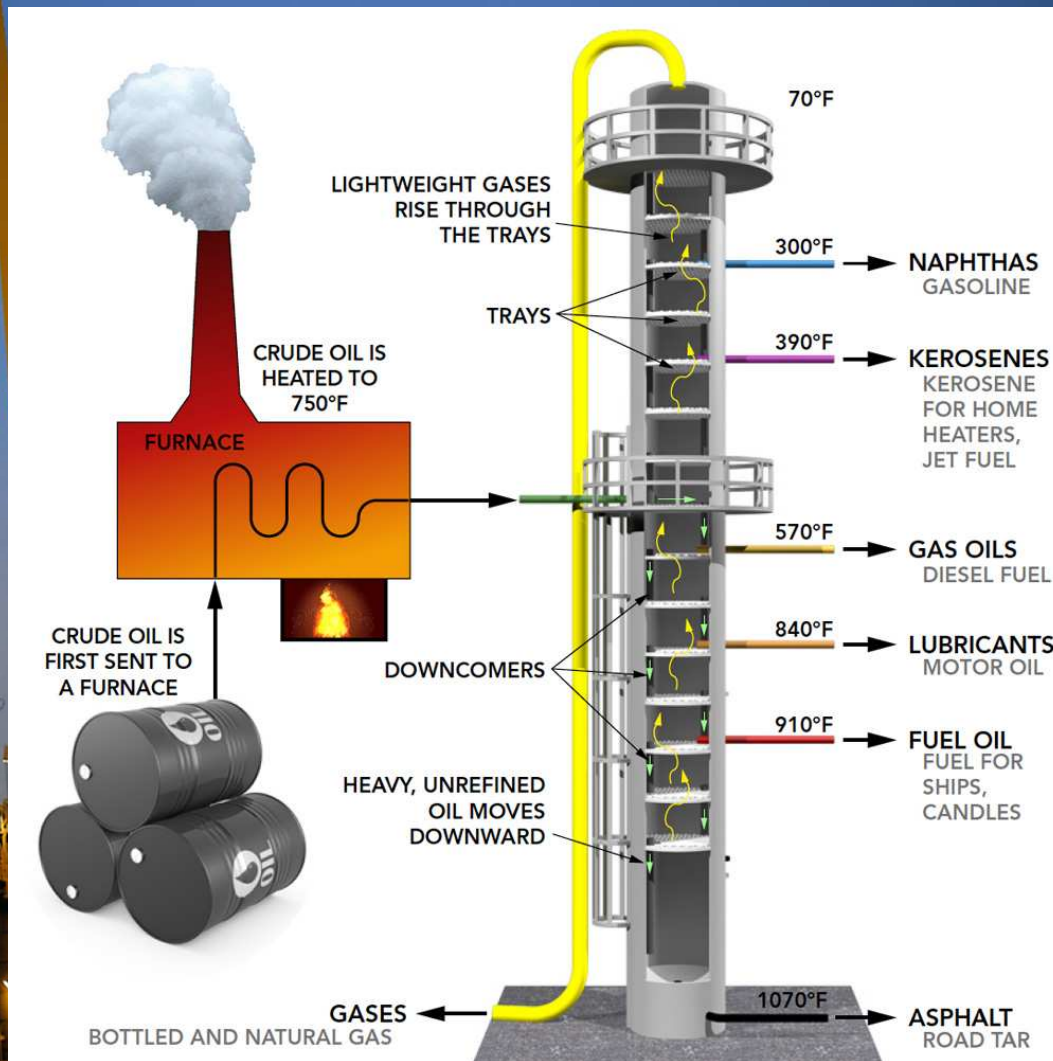


Oil Refinery

- Crude oils are not uniform, but rather are mixtures of thousands of different compounds called hydrocarbons. Each component of each compound has its own size, weight and boiling temperature.
- Crude oils have low value if not processed/refined.
- Petroleum refining is a physical and chemical process to transform crude oils into useful products.
- First, crude oils are washed in a desalter and then heated.
- Next, they enter the crude fractionator (tall vertical column) which separate the oil components based on each component's boiling point without chemical reaction.
- From crude fractionator, crude components are further processed, sometimes involving chemical reaction, to create higher value products.



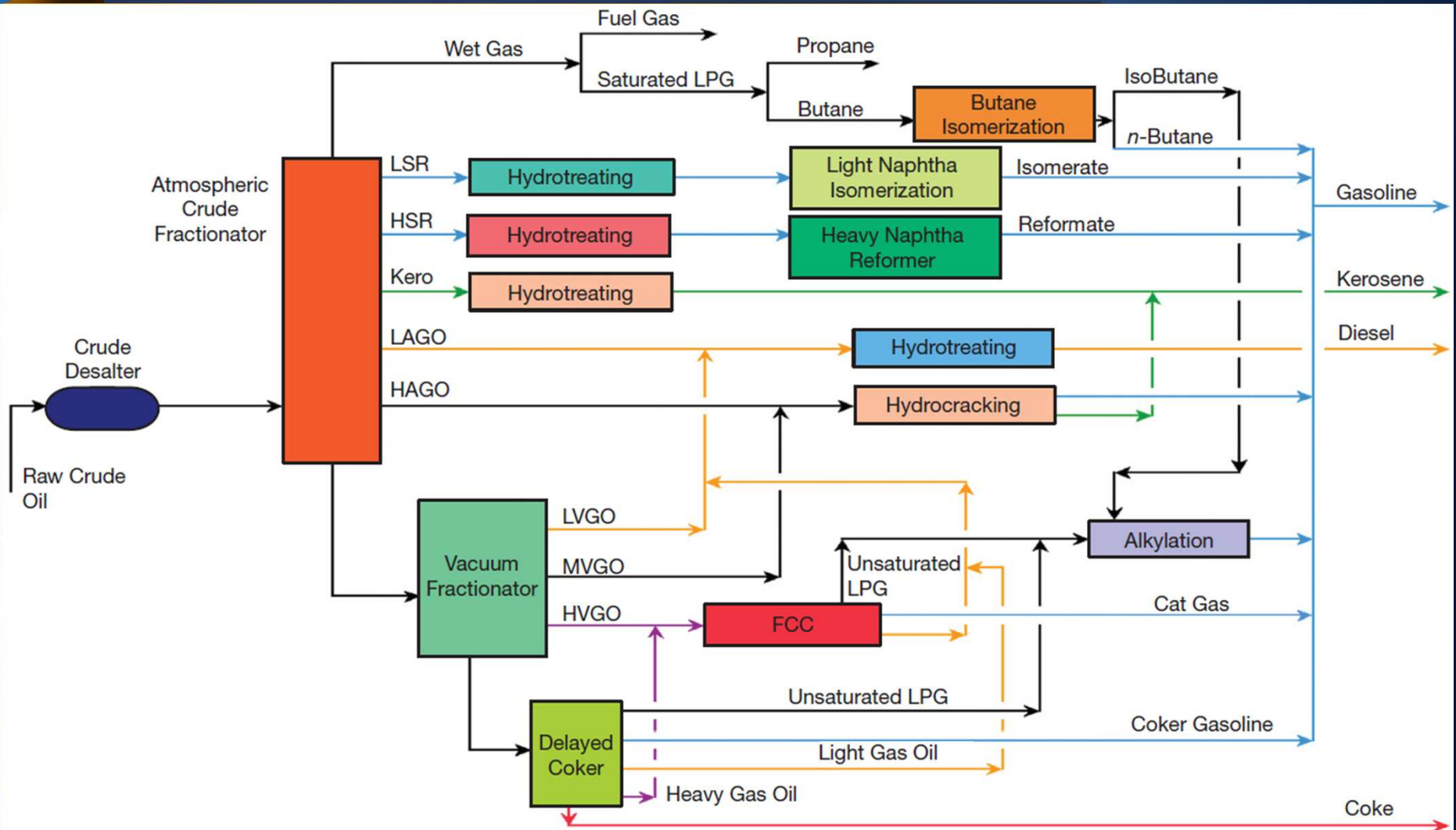
Simplified Oil Refinery Diagram



Refinery Products :

- Light distillates :
 - Liquid Petroleum Gas (LPG)
 - Gasoline (Petrol)
 - Naphtha (flammable liquid hydrocarbon mixtures)
- Middle distillates :
 - Kerosene
 - Diesel Fuel
 - Heating Oil
 - Light Fuel Oil
- Heavy distillates :
 - Heavy Fuel Oil
 - Bunker Fuel Oil
 - Asphalt

More Complex Oil Refinery Diagram

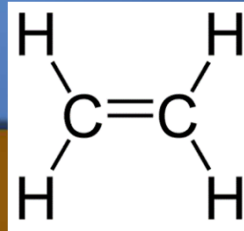


▲ **Figure 1.** This refinery flow diagram demonstrates how raw crude oil is converted into fuels.

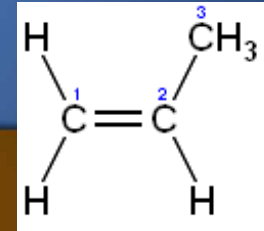
LSR = light straight-run naphtha. HSR = heavy straight run naphtha. Kero = kerosene. LAGO = light atmospheric gas oil.

HAGO = heavy atmospheric gas oil. LVGO = light vacuum gas oil. MVGO = medium vacuum gas oil. HVGO = heavy vacuum gas oil.

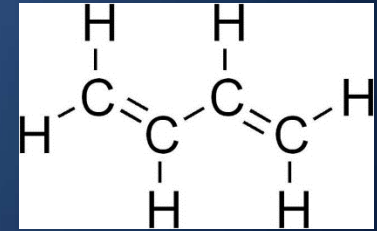
Petrochemical



ethylene

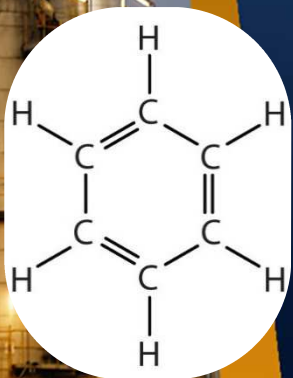


propylene

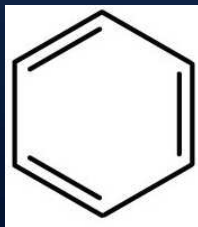


butadiene

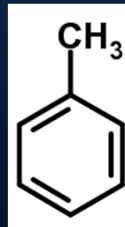
- It is a chemical product derived from petroleum.
- Primary petrochemical are divided into 3 groups based on their chemical structures :
 - Olefins includes ethylene (C_2H_4), propylene (C_3H_6), and butadiene (C_4H_6). Ethylene and propylene are important sources of industry chemicals and plastic products. Butadiene is used in making synthetic rubber. Olefin is produced by fluid catalytic cracking of petroleum fraction or steam cracking of natural gas liquid.
 - Aromatics includes benzene (C_6H_6), toluene (C_7H_8), and xylenes (C_8H_{10}) or BTX. Benzene is a raw material for dyes and synthetic detergents. Benzene and toluene is used in making polyurethanes. Xylenes is used to produce plastics and synthetic fibers. Aromatics are produced by catalytic reforming of naphtha.
 - Synthesis gas is a mixture of carbon monoxide (CO) and hydrogen (H_2) used to make ammonia and methanol. Ammonia is used to make the fertilizer urea and methanol is used as a solvent and chemical intermediate.



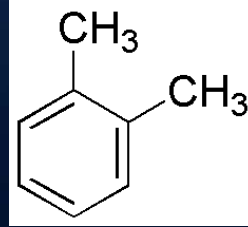
or



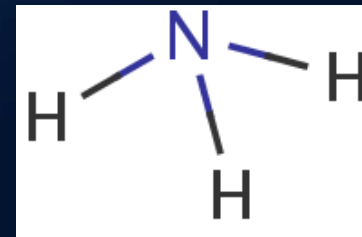
benzene



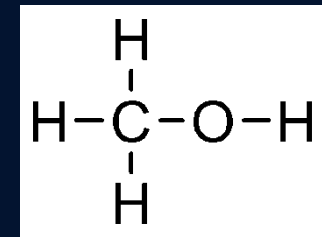
toluene



xylene

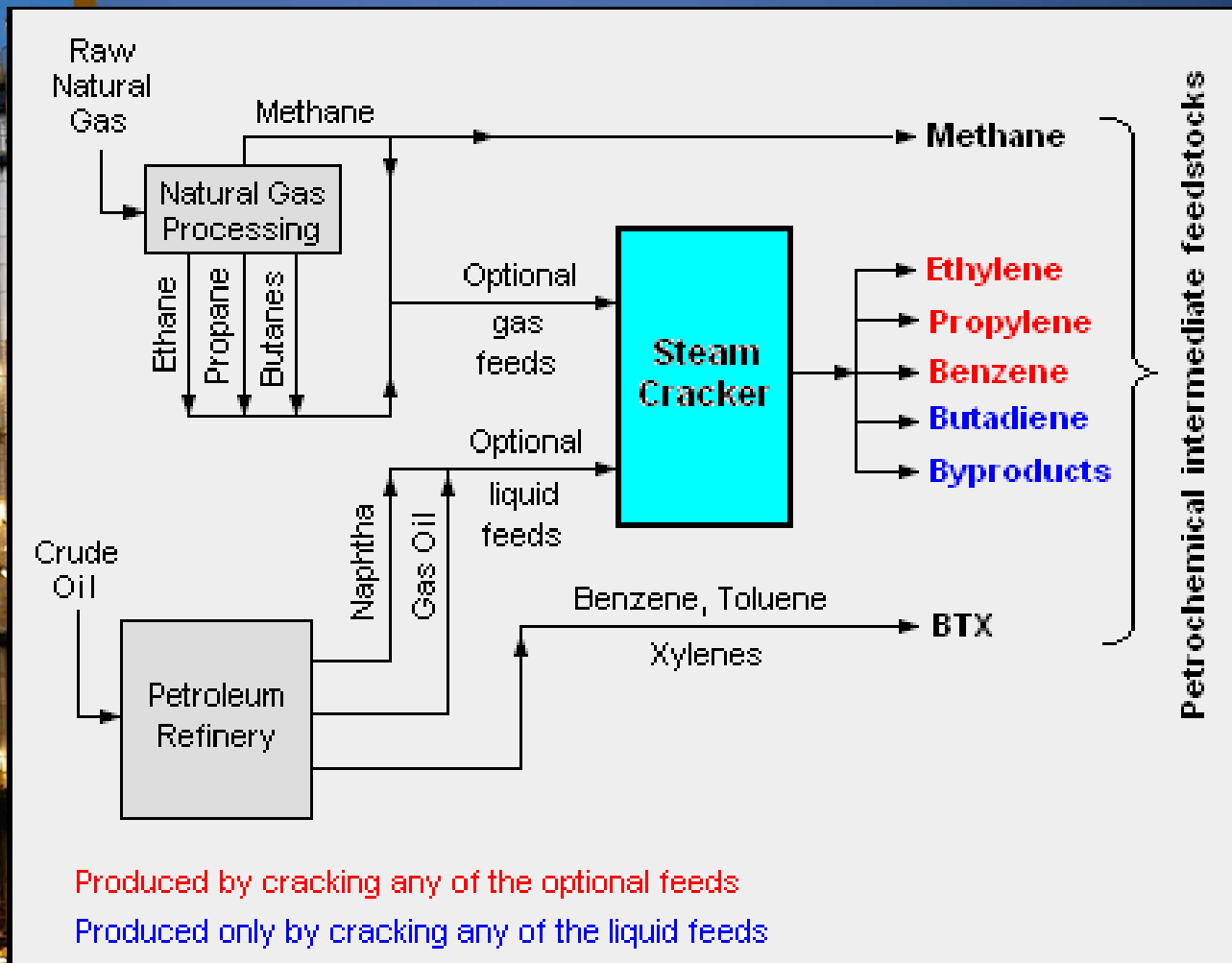


ammonia



methanol

Petrochemical Simplified Diagram



Fluid Catalytic Cracking is a chemical process using liquid catalyst to create new, smaller molecules from larger molecules (cracking) to make gasoline and distillate fuels.

Steam Cracking is a chemical process using steam to thermally crack the feedstock into lighter hydrocarbon.

Marketing

- Downstream consumers includes commercial and retail consumers.
- Commercial consumers includes petrochemical & industrial manufacturers, utilities (especially power plant), transportation fleets (airlines, trucks, vessels), and municipalities.
- Downstream industry may also only involve in distribution and sales of petroleum product, either to commercial or retail consumer, without having any plant.
- Downstream product pricing, especially mass product like gasoline, highly depends on oil price. However, specialized product like racing lubricant is less sensitive to oil price.



The slide features a dark blue background with a vertical orange stripe on the left side. On the far left, there is a photograph of an industrial facility, likely an oil refinery or gas processing plant, showing tall distillation columns and scaffolding. The title 'Oil & Gas Industry Sector Boundary' is written in a bold, yellow font within a dark orange horizontal banner that overlaps the top of the orange stripe.

Oil & Gas Industry Sector Boundary

- Actually, the boundary between upstream, midstream, and downstream is sometimes not clear / gray area.
- Pipeline from upstream industry to downstream industry may be owned by upstream company or independent midstream company.
- LNG industry is normally considered midstream or downstream industry, however with FLNG revolution, it is now part of upstream sector.
- Due to large investment & complex requirement, normally a company only involve in one sector only, however some very large companies involve in upstream-midstream-downstream sector, known as integrated oil & gas companies, i.e. Shell, ExxonMobil, and Petronas.



Thank You
تریمما کاسیہ

About the Author



Puput Aryanto Risanto , PMP is a Project Management Professional certified Sr. Project Engineer with more than 12 years experience in Oil & Gas industry. Currently he is working for Premier Oil Natuna Sea B.V. in Jakarta, Indonesia. Previously, he worked for Petronas Carigali Sdn. Bhd. at KL, Premier Oil Natuna Sea B.V. at Jakarta and Total E&P Indonesie at Balikpapan, Indonesia. His expertise included project engineering & management, field development, joint venture management, EPCIC management, and electrical engineering-construction-inspection. He can be contacted at email aryantorisanto@yahoo.com or linkedin Puput Aryanto Risanto.