E-TUTORIAL FOR 3rd SEMESTER

ENS18301CR: Natural Resources

Credit IV: Energy resources

1.2. Non Renewable Energy Resources

Prepared by

Dr. Moieza Ashraf

Deptt. Of Environmental Science

NON-RENEWABLE ENERGY RESOURCES

Energy exists freely in nature; some of them are infinitely available called renewable. A non-renewable energy is one that does not renew itself at a sufficient rate for sustainable economic extraction in meaningful human time frames.

The non-renewable energy is energy from fossil fuels such as coal, crude oil, natural gas and uranium. Unlike renewable energy, non renewable energy need human intervention to make it suitable for consumption. Fossil fuels are mainly made up of carbon. It is believed that fossil fuels were formed over 300 million years ago when the earth was different in its landscape.

TYPES OF NON-RENEWABLE ENERGY:

The resources for non-renewable energy are mainly fuels from fossil deposits. The most common non-renewable resources are:-

- Coal
- Petroleum products
- Compressed natural gas

Apart from fossil fuels, nuclear fuels are also non-renewable.

FOSSIL FUELS:

Fossil Fuels are formed by the remains of animals and plants. Fossil fuel is divided into three categories and is stated below:

1. COAL:

Coal is a combustible black or brownish-black sedimentary rock, formed as rock strata called coal seams. Coal is mostly carbon with variable amounts of other elements; chiefly hydrogen, sulfur, oxygen, and nitrogen. Coal is formed when dead plant matter decays into peat and is converted into coal by the heat and pressure of deep burial over millions of years. Coal varies widely in important physical characteristics such as energy content (usually measured in British Thermal Units, BTU), carbon percentage, moisture content, presence of contaminants such as sulfur, etc. These attributes determine both the price of coal, and the uses to which it can be put, primarily steel production, electricity generation, and heating

1.1. Composition:

The composition of coal is reported either as a proximate analysis (moisture, volatile matter, fixed carbon and ash) or an ultimate analysis (carbon, hydrogen, nitrogen, oxygen, and sulfur). The "volatile matter" does not exist by itself (except for some adsorbed methane) but designates the volatile compounds that are produced and driven off by heating the coal. A typical bituminous coal may have an ultimate analysis on a dry, ash-free basis of 84.4% carbon, 5.4% hydrogen, 6.7% oxygen, 1.7% nitrogen, and 1.8% sulfur, on a weight basis.

1.2. Formation:

One theory states that about 360 million years ago, some plants evolved the ability to produce lignin, a complex polymer that made their cellulose stems much harder and woodier. Thus, the first trees evolved. But bacteria and fungus did not immediately evolve the ability to decompose lignin, so the wood did not fully decay but became buried under sediment, eventually turning into coal. About 300 million years ago, mushrooms and other fungi developed this ability, ending the main coal-formation period of earth's history.

At various times in the geologic past, the Earth had dense forests in low-lying wetland areas. Due to natural processes such as flooding, these forests were buried underneath soil. As more and more soil deposited over them, they were compressed. The temperature also rose as they sank deeper and deeper. As the process continued the plant matter was protected from biodegradation and oxidation, usually by mud or acidic water. This trapped the carbon in immense peat bogs that were eventually covered and deeply buried by sediments. Under high pressure and high temperature, dead vegetation was slowly converted to coal.

This conversion of dead vegetation into coal is called coalification. Coalification starts with dead plant matter decaying into peat. Then over millions of years the heat and pressure of deep burial causes the loss of water, methane and carbon dioxide and an increase in the proportion of carbon. Thus first lignite (also called "brown coal"), then sub-bituminous coal, bituminous coal, and lastly anthracite (also called "hard coal" or "black coal") may be formed.

The wide, shallow seas of the Carboniferous Period provided ideal conditions for coal formation, although coal is known from most geological periods. As geological processes apply pressure to dead biotic material over time, under suitable conditions, its metamorphic grade or rank increases successively into:

a) **PEAT,** a precursor of coal. A mass of recently accumulated to partially carbonized plant debris. Peat is an organic sediment. Burial, compaction, and coalification will transform it into coal, a rock. It has a less carbon content on a dry ash-free basis.

b) **LIGNITE,** or brown coal, the lowest rank of coal, most harmful to health, used almost exclusively as fuel for electric power generation. This is the softest, youngest, and wettest rank of coal, often referred to as "brown coal" with a low carbon content (Table.1.) and correspondingly lower energy content.

c) **SUB-BITUMINOUS COAL,** whose properties range between those of lignite and those of bituminous coal, is used primarily as fuel for steam-electric power generation.

d) **BITUMINOUS COAL,** a dense sedimentary rock, usually black, but sometimes dark brown, often with well-defined bands of bright and dull material. It is used primarily as fuel in steam-electric power generation and to make coke. This is the second rank of coal, softer and younger than anthracite, and containing a lower percentage of carbon (75-92%) and therefore more moisture and volatiles. This rank of coal is used for electricity generation as well as for steel production and possesses an average "as-received" energy content of 24 million BTU /ton in the US.

e) **ANTHRACITE,** the highest rank of coal is a harder, glossy black coal used primarily for residential and commercial space heating. This is the highest ranked, hardest, oldest, and least common type of coal. It possesses a high energy content, high percentage of carbon (>90%) and relatively little moisture or volatiles. In the US anthracite is used primarily for residential heating and for some industrial processes and possesses an average "as-received" (including moisture and other minerals) energy content of 25 million BTU /ton

Coal can contain up to 10% sulfur by weight, although values of 1-4% are more typical depending on the region where the coal was extracted. Sulfurous gases (primarily sulfur dioxide) produced by the combustion of fossil fuels are the major cause of acid rain and contribute to other pollution related health problems. Ever since the 1990 revisions to the Clean Air Act, there have been tight restrictions on the amount of sulfur that can be released into the atmosphere as a result of the combustion of fossil fuels. There are three ways to reduce sulfur emissions from burning coal; the first is through crushing/washing the coal which physically separates some of the sulfur from the coal. The second method is through the use of "scrubbers" which remove most of the sulfur from the combustion gases before they are released into the atmosphere. Lastly, plants can burn younger coals that contain less sulfur, such as the coal found in Alaska (average .3% sulfur by weight).

Table.1. Coal types composition:

COAL COMPOSITION						
Type of Coal	**%C**	**%H**	**%O**	**%N**	**%Moisture**	**Heating Value (kcal/kg)**
*Peat is a dark, woody soil that has not yet been coalified to lignite.						
Anthracite	92–95	3–4	2–3	0–2	1–4	7500–8000
Bituminous	75–92	4–6	3–20	1–2	5–30	5000–8000
Lignite	60–75	4–6	17–35	1–2	30–50	3000–4500
Peat*	45–60	3–7	20–45	1–3	70–90	<3000

Table. 2. Top countries by coal production:

Coal production (million tonnes)						
Country/Region	**2018**	**2016**	**2015**	**2014**	**2013**	**2007**
China	3,523.2	3,411.0	3,747.0	3,874.0	3,974.3	2,536.7
India	716.0	692.4	677.5	648.1	608.5	478.2
United States	702.3	660.6	812.8	906.9	893.4	1,039.2
EU	490.1	484.7	528.1	491.5	557.9	590.5
Australia	481.3	492.8	484.5	503.2	472.8	393.9
Indonesia	461.0	434.0	392.0	458.0	474.6	174.8
Russia	411.2	385.4	373.3	357.6	355.2	314.2
South Africa	252.3	251.2	252.1	260.5	256.3	269.4
Germany	175.1	176.1	183.3	185.8	190.6	201.9
Poland	127.1	131.1	135.5	137.1	142.9	145.8

2. Oil:

Oil was made out of animal and plant remains, of animals that had lived in water many millions years ago.

The first step was 300-400 millions of years ago. Then remains started to sediment on ocean’s bottom and with time all was covered with sand and mud. Before 50-100 millions years those remains were already covered with big layer of sand and mud which created huge pressures and high temperatures. As a result of these conditions raw oil as well as natural gas turned up. Today we drill through the huge layers of mud, sand and cliffs in order to get to oil wells.

The whole process of obtaining oil starts with:

2.1. Locating the field

Seismic surveys are used by geologists and geophysicists to search for geological structures that may form oil reservoirs. The method includes making an underground explosion nearby and observing the seismic response, which provides information about the geological structures underground. Other instruments such as gravimeters and magnetometers are also used in the search for petroleum. Extracting crude oil normally starts with drilling wells into an underground reservoir. When an oil well has been tapped, a geologist will note its presence. Often many wells (called *multilateral wells*) are drilled into the same reservoir, to an economically viable extraction rate.

2.2. Drilling

The oil well is created by drilling a long hole into the earth with an oil rig. A steel pipe (casing) is placed in the hole, to provide structural integrity to the newly drilled well bore. Holes are then made in the base of the well to enable oil to pass into the bore. Finally, a collection of valves called a "Christmas tree" is fitted to the top; the valves regulate pressures and control flow. The drilling process comes under "upstream", one of the main services in the oil industry, along with mid-stream and downstream.

2.3. Oil extraction and recovery

- **Primary recovery**

During the *primary recovery stage*, reservoir drive comes from a number of natural mechanisms. These include: natural water displacing oil downward into the welland gravity drainage resulting from the movement of oil within the reservoir from the upper to the lower parts where the wells are located. Recovery factor during the primary recovery stage is typically 5-15%.

While the underground pressure in the oil reservoir is sufficient to force the oil (along with some associated gas) to the surface, all that is necessary is to place a complex arrangement of valves (the Christmas tree) on the well head to connect the well to a pipeline network for storage and processing. Sometimes pumps, are used to bring the oil to the surface; these are known as artificial lifting mechanisms.

- **Secondary recovery**

Over the lifetime of a well, the pressure falls. At some point there is insufficient underground pressure to force the oil to the surface. After natural reservoir drive diminishes, *secondary recovery* methods are applied. These rely on supplying external energy to the reservoir by injecting fluids to increase reservoir pressure, hence increasing or replacing the natural reservoir drive with an artificial drive. Secondary recovery techniques increase the reservoir's pressure by water injection, gas reinjection and gas lift. Gas reinjection and lift each use associated gas, carbon dioxide or some other inert gas to reduce the density of the oil-gas mixture, and thus improve its mobility.

- **Enhanced recovery**

Enhanced, or tertiary oil recovery methods, increase the mobility of the oil in order to increase extraction.

Thermally enhanced oil recovery methods (TEOR) are tertiary recovery techniques that heat the oil, reducing its viscosity and making it easier to extract. Steam injection is the most common form of TEOR, and it is often done with a cogeneration plant. This type of cogeneration plant uses a gas turbine to generate electricity, and the waste heat is used to produce steam, which is then injected into the reservoir. Occasionally, surfactants are injected to alter the surface tension between the water and the oil in the reservoir, mobilizing oil which would otherwise remain in the reservoir as residual oil.

The use of microbial treatments is another tertiary recovery method. Special blends of the microbes are used to treat and break down the hydrocarbon chain in oil, making the oil easy to recover. It is also more economical versus other conventional methods. In some states such as Texas, there are tax incentives for using these microbes in what is called a secondary tertiary recovery. Very few companies supply these.

2.4. <u>Recovery rate:</u>

The amount of oil that is recoverable is determined by a number of factors, including the permeability of the rock, the strength of natural drives (the associated gas present, pressure from adjacent water or gravity), porosity of the reservoir rock, i.e. the rock storage capacity, and the viscosity of the oil. When the reservoir rocks are "tight", as in shale, oil generally cannot flow through, but when they are permeable, as in sandstone, oil flows freely.

2.5. Petroleum refining processes which are the chemical engineering processes and other facilities used in petroleum refineries (also referred to as oil refineries) to transform crude oil into useful products such as liquefied petroleum gas (LPG), gasoline or petrol, kerosene, diesel oil and fuel oils. Refineries are very large industrial complexes that involve many different processing units and facilities such as utility units and storage tanks. Each refinery has its own unique arrangement and combination of refining processes largely determined by the refinery location, desired products and economic considerations.

- **<u>Processing units used in refineries:</u>**

a) <u>Crude Oil Distillation unit</u>: Distills the incoming crude oil into various fractions for further processing in other units.

b) Vacuum distillation unit: Further distills the residue oil from the bottom of the crude oil distillation unit. The vacuum distillation is performed at a pressure well below atmospheric pressure.

c) Naphtha hydro treater unit: Uses hydrogen to desulfurize the naphtha fraction from the crude oil distillation or other units within the refinery.

d) Catalytic reforming unit: Converts the desulfurized naphtha molecules into higher-octane molecules to produce *reformate*, which is a component of the end-product gasoline or petrol.

e) Alkylation unit: Converts isobutene and butylene's into *alkylate*, which is a very high-octane component of the end-product gasoline or petrol.

f) Isomerization unit: Converts linear molecules such as normal pentane into higher-octane branched molecules for blending into the end-product gasoline. Also used to convert linear normal butane into isobutene for use in the alkylation unit.

g) Distillate hydro treater unit: Uses hydrogen to desulfurize some of the other distilled fractions from the crude oil distillation unit (such as diesel oil).

h) Merox (mercaptan oxidizer) or similar units: Desulfurize LPG, kerosene or jet fuel by oxidizing undesired mercaptans to organic disulfides.

i) Amine gas treater, Claus unit, and tail gas treatment for converting hydrogen sulfide gas from the hydro treaters into end-product elemental sulfur. The large majority of the 64,000,000 metric tons of sulfur produced worldwide in 2005 was byproduct sulfur from petroleum refining and natural gas processing plants.[11][12]

j) Fluid catalytic cracking (FCC) unit: Upgrades the heavier, higher-boiling fractions from the crude oil distillation by converting them into lighter and lower boiling, more valuable products.

k) Hydrocracker unit: Uses hydrogen to upgrade heavier fractions from the crude oil distillation and the vacuum distillation units into lighter, more valuable products.

l) Visbreaker unit upgrades heavy residual oils from the vacuum distillation unit by thermally cracking them into lighter, more valuable reduced viscosity products.

m) Delayed coking and fluid coker units: Convert very heavy residual oils into end-product petroleum coke as well as naphtha and petrol oil by-products.

Top ten leading producers of oil production are presented in Table 3.

Table. 3. Top countries by oil production:

	Country	**Oil production 2019 (bbl/day)**	**Oil production per capita 2017 (bbl/day/million people)**
-	World production	80,622,000	10,798
01	United States[6]	15,043,000	35,922
02	Saudi Arabia (OPEC)	12,000,000	324,866
03	Russia	10,800,000	73,292
04	Iraq (OPEC)	4,451,516	119,664
05	Iran (OPEC)	3,990,956	49,714
06	China	3,980,650	2,836
07	Canada	3,662,694	100,931
08	United Arab Emirates (OPEC)	3,106,077	335,103

09	Kuwait (OPEC)	2,923,825	721,575
10	Brazil	2,515,459	12,113

2.6. <u>Oil sands, tar sands, crude bitumen</u>, or more technically bituminous sands, are a type of unconventional petroleum deposit. Oil sands are either loose sands or partially consolidated sandstone containing a naturally occurring mixture of sand, clay, and water, soaked with a dense and extremely viscous form of petroleum technically referred to as bitumen.

Natural bitumen deposits are reported in many countries, but in particular are found in extremely large quantities in Canada. Other large reserves are located in Kazakhstan, Russia, and Venezuela. The estimated worldwide deposits of oil are more than 2 trillion barrels (320 billion cubic metres); the estimates include deposits that have not been discovered. Proven reserves of bitumen contain approximately 100 billion barrels, and total natural bitumen reserves are estimated at 249.67 Gbbl (39.694×10^9 m^3) worldwide, of which 176.8 Gbbl (28.11×10^9 m^3), or 70.8%, are in Alberta, Canada.

2.7. <u>Oil Shale:</u> Oil shale is an organic-rich fine-grained sedimentary rock containing kerogen (a solid mixture of organic chemical compounds) from which liquid hydrocarbons can be produced, called shale oil. Shale oil is a substitute for conventional crude oil; however, extracting shale oil from oil shale is more costly than the production of conventional crude oil both financially and in terms of its environmental impact. Deposits of oil shale occur around the world, including major deposits in the United States. A 2016 estimate of global deposits set the total world resources of oil shale equivalent of 6.05 trillion barrels (962 billion cubic metres) of oil in place.

Heating oil shale to a sufficiently high temperature causes the chemical process of pyrolysis to yield a vapor. Upon cooling the vapor, the liquid shale oil, an unconventional oil is separated from combustible oil-shale gas (the term *shale gas* can also refer to gas occurring naturally in shales). Oil shale can also be burned directly in furnaces as a low-grade fuel for power generation and district heating or used as a raw material in chemical and construction-materials processing.

Oil shale gains attention as a potential abundant source of oil whenever the price of crude oil rises. At the same time, oil-shale mining and processing raise a number of environmental concerns, such as land use, waste disposal, water use, waste-water management, greenhouse-gas emissions and air pollution. Estonia and China have well-established oil shale industries, and Brazil, Germany, and Russia also utilize oil shale.

General composition of oil shales constitutes inorganic matrix, bitumens, and kerogen. Oil shales differ from oil-*bearing* shales, shale deposits that contain petroleum (tight oil) that is sometimes produced from drilled wells

3. <u>NATURAL GAS:</u>

This gas is mainly made out of the methane, a simple union that consists of one carbon atom and four hydrogen atoms. Methane is highly flammable with almost full combustion. After combustion, there are no ashes, and air pollution is almost negligible. Natural gas has no color, taste, smell or shape in its natural form, so it’s indiscernible to people. Because of this reason companies are adding chemical to it which has smell of rotten egg. That smell enables people easy detection of potential gas leaking in house.

Because of this event, this year is remembered as the beginning of the intentional use of natural gas In 19th century natural gas was almost solely used for street lamps. About year 1890, majority cities started using electrical energy for the illumination, so natural gas producers started to search new markets for their product. Robert Brunson invented in 1885 burner which mixed air with the natural gas. This invention has enabled exploit of natural gas for cooking and heating chambers. First more significant gas pipeline was built in 1891. It was 120 miles long, and was transporting gas from middle Indiana all the way to the Chicago. After this period very few gas pipelines were built until the end of the World war two. During the second world war, great progress in metal characteristics, welding techniques and pipes manufacturing was achieved, so pipelines manufacture became economically appealing, and extensively used in economy and households as well.

3.1. Extracting Natural Gas from Earth and Sea:

In many cases, natural gas is an ideal fossil fuel because it’s pretty clean, simple for transport and convenient for use. It’s cleaner than oil and coal, so it’s more and more spoken to be solution for actual climate changes and problems connected with poor air quality. Opposed to oil and coal, natural gas has bigger proportion hydrogen/carbon and has the smaller emission of the carbon dioxide to an atmosphere for the same amount of energy.

When extracting natural gas, limits of today’s technologies are still very obvious. Often, both oil and natural gas are pulled off from the same well. Like in a process of an oil production, part of natural gas comes independently on surface because of the big pressure in deepness. These types of gas wells are demanding only pipe system called “Christmas tree” for controlling the gas flow. Number of these wells is shrinking, because majority of this “cheap” gas is already pulled out. Because of this it’s almost always necessary to use some sort of pumping from underground.

Natural gas is found in different underground formations. Some formations are heavier and more expensive for exploit, but are also leaving the place for the improvement in future gas supply. After the natural gas is pulled to the surface, it gets brought across the gas pipeline system to containers, and after that to the final consumers as well.

3.2. Demand of Natural Gas:

Reserves are pretty big, but not endless. Russia leads the way, followed by countries of Middle East. Middle East’ countries are for now more concentrated on oil production, and this is the reason why they lack bigger natural gas production. This gives them high future potential, because when oil exploit will be coming to an end, their economies will be transformed to the natural gas production. At this moment U.S.A is the biggest natural gas producer with, followed by Russia (Table 4).

Table. 4. Top countries by Natural Gas:

Rank	Country	Continent	Annual NG production (millionm^3)
1	USA	North America	766,200
2	Russia	Eurasia	598,600
3	Iran	Asia	184,800
4	Qatar	Asia	188,000

5	Canada	North America	149,900
6	China	Asia	138,400
7	Norway	Europe	117,200
8	Saudi Arabia	Asia	102,300
9	Turkmenistan	Asia	83,700
10	Algeria	Africa	83,290

4. Nuclear fuels:

Nuclear power provides about 6% of the world’s energy and 13–14% of the world’s electricity. Therefore it is also included under non renewable resources category. The use of nuclear technology relying on fission requires naturally occurring radioactive material as fuel. Uranium is the most common fission fuel, and is present in the ground at relatively low concentrations and mined in 19 countries.