

Chemical Technology
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Module - 2
Coal Chemical
Lecture - 1
Coal and Coal as Chemical Feed Stock

We are discussing organic chemical technology course, in module 1 we discussed about the introduction to chemical process industry. In lecture 1 and in lecture 2, we discussed about the raw material for chemical process industry and in the 3 rd, various unit process and unit operation, which are being used in the chemical process industry. Now, we will be discussing module 2, in the module 2 contains 3 lectures, lecture 1 that will deal with the Coal and Coal as Chemical Feed Stock for the chemical process industry.

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Introduction

Coal is major source of energy. It provides 25% of total world's total energy consumption and generates 40% of the world's electricity.

- There has been continuous development in utilisation of coal as source of oil as substitute of petroleum based fuel and Chemical feed stock since beginning of nineteenth century and again gaining importance due to rising cost of crude oil and limited oil reserves

As you know, the coal is the major source of energy; it provides 25 percent of the total world energy consumption and generates 40 percent of the world's electricity. There has been continuous development in utilisation of coal, as source of oil as substitute of petroleum based fuel and chemical feed stock, since beginning of the 19 th century and again, gaining importance due to rising coast of crude oil and limited oil resources.

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Introduction

- Most of the chemicals derived from coal was by destructive distillation of coal furnishing mostly aromatics and Acetyne Route using Coal and Lime stone
- However with the advancement of technology many other chemicals are being made from coal.
- Now coal being considered future raw material for fuel and chemicals through synthesis gas along with its major use as primary source of energy.

Most of the chemicals derived from the coal was by destructive distillation of coal, furnishing mostly aromatic and acetyne route using coal and lime stone. However, with the advancement of technology, many other chemicals are being made from the coal. Now, coal being considered future raw material for fuel and chemicals through synthesis gas along with it is major use, as primary source of the energy.

One question come to mind, why coal as a chemical feed stock because you see the coal from very beginning of the 19 th century before coming of the petroleum and the petrol chemical energy. Coal was the root, from which we are producing many of the chemicals especially, the aromatic if in some of the inorganic chemicals, we are also produced from the coke oven plant.

So, this was the route and this is the reason, why the again the people are having the interest, even the coal to liquid technology during the 1930 German, they worked on the production of the gasoline from the coal. But, only because of the economical reason and with the ability of the crude and petroleum, the process was not actually commercialized.

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Coal And Coal as Chemical Feed Stock

- Coal is the largest source of energy all over the world.
- Power production
- Synthetic fuel : gaseous and liquid
- Coke production
- Chemicals which are now being derived from petroleum and natural gas route

As I discussed earlier, the Coal is the largest source of energy all over the world and the power production. But, the other routes where, we are using the coal, that is the synthetic fuel that may be in the form of the gaseous liquid. Coke production that in the coke oven plant, where we are producing the coke from the coal and during the production of the coke, we are generating coke oven gas.

Chemicals which are now being derived for petroleum, natural gas route that can be produced from the coal through this synthesis gas route or through the calcium carbide route. Recent development in utilization of the coal, coal gasification that is being used as a fuel from the synthesis gas to the FT synthesis and the fertilizer feed stock. Already, we are we are having the two fertilizer plant based on the coal during the initial stage of the development of the fertilizer industry in India.

That was the one in the Ramagundam, another was in the Talci, but because of the economic reason, these two units because they were the low capacity (()). Coal to synthesis gas, that is the ammonia and the other chemicals, that we are making from the synthesis gas. Synthesis gas means, when we are taking the hydrogen nitrogen from the synthesis gas then it is going through the fertilizer plant for the making of the ammonia. And as you know, the ammonia that is one of the major feed stock not only for the chemical fertilizer industry, also for the chemical industry. Coal to oil through the FT

synthesis, as I told you earlier also that the coal to coal to oil through FT synthesis, lot of the work done was done during the initial stage.

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Coal and Coal as chemical feed stock

Recent Development In Utilization Of Coal:

- ❖ Coal to synthesis gas: Ammonia and other chemicals
- ❖ Coal to oil through FT synthesis
- ❖ Coal to methanol and olefin
- ❖ Coal to dimethyl ether through methanol,
- ❖ Coal to plastic methanol to olefin technology
- ❖ Coal gasification: fuel and fertiliser feed stock

But, only because of the economic reason, the process could not be commercialized but again there has been recent interest on this. Coal to methanol and olefin technology, that is coming in a big way from the coal gasification to synthesis gas, synthesis gas to methanol and methanol to olefin (()), that is the mto technology methanol to olefin.

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Coal and Coal as chemical feed stock

These future technologies are likely to play important role in providing alternate feed stock for chemical industries.

Coal to dimethyl ether through the methanol route, that is also getting important because dimethyl ether that can be directly blend with the gasoline. Coal to plastic through the methanol to olefin technology, because the during the process, we will produce the propylene and propylene to plastic are even the ethylene is also produced in the process. And so the coal to plastic technology, already in china, they are going to have a plant based on the coal to plastic technology. Coal and coal as chemical feed stock, these future technology are likely to play important role in providing the alternate feed stock for chemical industry. Let us discuss now, about the, in very brief about the coal origin and the composition.

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Coal Origin And Composition

- Coal is carbonaceous solid black or brownish black sedimentary rock matter vegetation, biological changes originated from the accumulation of partially decomposed vegetation.
- Formation of Coal started 250-300 million years ago
- Biological changes and subsequent effects of temperature and pressure altered these deposits to coal.

Coal is the carbonaceous solid black or the brownish black sedimentary rock, matter vegetation, biological changes originated from the accumulation of the partially decomposed vegetation. Formation of the coal is started 250 to 300 millions years ago and that had taken long time, in the coal which you are seeing now and this formed, that took around 250 to 300 million years. Biological changes and subsequent effects of the temperature and pressure alter these deposits to coal.

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Coal Origin And Composition

- Coal is composed of chiefly carbon and other elements like hydrogen, sulphur, oxygen, nitrogen, moisture and noncombustible inorganic matter containing, silica, iron, calcium, magnesium, mercury etc.

Coal is composed of chiefly the carbon and other elements like hydrogen, sulphur, oxygen, nitrogen, moisture and non combustible inorganic matter containing silica, iron, calcium, magnesium and mercury. Mercury now again a rear the problem of mercury machine that was not there form the thermal power plant. But in many of the coals, the amount of the mercury that is very high and the mercury machine that has been reported in the thermal power plant so, the mercury again is a problem in case of the especially, thermal power plant.

So, for the coal composition as you are seeing here, the we are having the carbon and hydrogen, apart from this, some of the undesirable part is also there, that is the sulphur, which is creating lot of problem. Because, the coal is the sulphur content in the coal is varying widely from one place to another place, just the take the case of the Assam coal, that it contain very high sulphur and the other material, which are creating problem.

That is, the silica, iron, calcium, magnesium compound, they are coming as as after the burning of the coal or the gasification. So, that is a big problem in case of the where, the ash content is high. As in our country, the ash content is very high that is, varying from 30 to 40 percent in major coal reserve.

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Coal Origin And Composition

- Coal is highly complex and heterogeneous substance
- Coal has a wide range of composition. The composition, sulphur content, mercury content and calorific value of the coal vary widely from one coal reserve to another coal reserve.
- Coal may be hard or slightly softer depending on the source.

Coal is highly complex and heterogeneous substance, coal has a wide range of composition, the composition is sulphur content, mercury content, calorific value of the coal vary widely from one coal reserve to another coal reserve. Coal may be hard or slightly softer depending upon the source, Assam coal is much softer than the other coal. And so, that was the problem in utilization of the Assam coal in the initial stage, when we try to use the Assam coal in the boiler.

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Coal Resources

- Category of coal resources are based on degree of assurance
- i) Coal Reserves
 - Proved
 - Indicated
 - Inferred
- (II)Depth Range

Coal resources, category of the coal resources are based on the degree of assurance that is, the coal reserve, proved reserve, indicated inferred or the depth range. So, these are two basis for the categorization of the coal resources, let us discuss the definition of the proved reserve or indicated reserve.

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Coal Resources

- **Proved Reserve** : Coal resources which has been reliably estimated and can be recovered economically.
- **Indicated Reserves** : Coal resource based on combination of direct measurement and reasonable geological assumptions.
- **Inferred Reserves**: Coal based on the assumed continuity of coal beds. Depth range determines the economy of extraction and a cope of exploration.

So, proved reserve the coal resource, which has been reliably estimated and can be recovered economically so, that we called, that is coming in the category of the proved reserve. Indicted reserve means, coal resource based on the combination of direct measurement and reasonable geological assumption. Then the inferred reserve, coal based on the assumed continuity of the coal bed's depth range determines the economy of the extraction and the scope of the exploration. Composition of the Indian coal and coal in other countries if you compare, the ash content that is very high in Indian coal.

That is, around 30 to 40 percent in other country, the ash content is less, sulphur content is, here also although it is less in compare to ash content in other country. Carbon 25 to 30 percent and other country, the carbon content that is high, hydrogen less than 3, calorific value is also less that the in the coal Indian coal, especially.

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Composition of Indian Coal and Coal in Other Countries		
Details	Indian coal	Coal in other countries
Ash content	30-40%	1-16%
Sulphur	0.5%	As high as 1.8%
Carbon	25-30%	53-57%
Hydrogen	<3%	4-6%
Calorific value	2450-3000	5000-6400

Source Visuvasam et al, 2005

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Coal Reserves	
<ul style="list-style-type: none">• World's proven coal reserves are estimated at about 860 billion tonnes which is expected to last up to 120 years at the current level of production.•• The global coal reserves consist of 53% anthracite and bituminous coals, 30% sub-bituminous and 17% lignite [BP statistics 2011, EIA, US Departments of Energy].	

Coal reserve, world's proven coal reserves are estimated at about 860 billion tonnes, which is expected to last for about 120 years at the current level of production and utilization. The global coal reserves consist of 53 percent anthracite and bituminous coal, 30 percent sub-bituminous coal, 17 percent of lignite. Largest coal reserves of coal are in China, USA, Russia, Australia and India, India has the 5th largest coal reserve in the world of the total coal reserve. Delhi 88 percent of non-coking coal reserves, while tertiary coals reserves account for measure 0.5 percent and the balance is the coking coal.

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Coal Reserves

- ❖ Coal deposits are chiefly located in Jharkhand, Orissa, Chattishgarh, West Bengal, Madhya Pradesh, Andhra Pradesh and Maharashtra.
- ❖ Coal reserves of India up to the depth of 1200meters have been estimated to be 276.81 billion tones as on April 1, 2010.

Coal deposits are chiefly located in Jharkhand, Orissa, Chhattisgarh, West Bengal, Madhya Pradesh, Andhra Pradesh and Maharashtra. In India, coal reserves from India upto the depth of 1200 meters have been, that is not 1200, 120 meters have been estimated to be 276.81 billion tones as on April 1, 2010.

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Coal Production and Consumption

- The global coal production in 2011 was 7 billion tones of which China accounted for approximately half of the production and consumption.
- Total coal production in India during 2009-10 was 532.29 million tones.
- Lignite production in 2009-10 was 23.95 million tonnes.

The global coal production in 2011 was 7 billion tonnes, of which china accounted for approximately half of the production and consumption. And this is the reason, how the now the coal in china that is been also used for the production became. Total coal

production in India during 2009 and 10 was 532.2 million tonnes, lignite production in 2009 and 10 was 23.95 million tonnes.

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Coal Reserves

- ❖ Lignite reserves in the country have been estimated around 39.90 billion tones as on March31, 2010.
- ❖ Major deposits are in Tamilnadu.

Lignite reserves in the country have been estimated around 39.9 billion tonnes as on March 31 st, 2010 and major deposits are in Tamil Nadu. In Tamil Nadu, some of the plants are there, which are using the lignite as a source of power and as the source of chemical.

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Coal Resources in India

Resources MT	Proved	Indica-ted	Inferred	Total
Coking coal	17,669	13,703	2,102	33,474
Non-coking coal	95,739	12,368	31,488	250,895
Tertiary coals	594	99	799.49	1,493
Total	114,001	137,471	34,389	285,862

Source: Geological survey of India Cited from emerging opportunities and challenges coal sector WEC-JMC 23 January 2012

This is the status of the coal reserve in India coking coal, non coking coal, tertiary coal and the total coal that is the proved, indicated, inferred.

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Coal demand Projections (million tonnes)				
Plan	Period	Power	Non-power	Total
11 th	2011/12	436	164	627
12 th	2016/17	603	221	824
13 th	2021/22	832	299	1131
14 th	2026/27	1109	408	1517
15 th	2031/32	1475	562	2037

Source: Integrated Energy Policy, Planning commission

Coal demand projection in the 11 th, 12 th, 13 th, 14 th, 15 th plan, these are the some of the figures that is available. And so, you can get an idea about the, what is the coal demand during the next few years.

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Distribution of Coal Resources (million tonnes)				
State	Proved	Indicated	Inferred	Total
Andhra Pradesh	9194	6738	2985	18927
Arunachal Pradesh	31	40	19	90
Assam	348	36	3	387
Bihar	-	-	160	160
Chhattisgarh	10910	29192	4381	44483
Jharkhand	39480	30894	6338	76712

Source: Geological survey of India Cited from emerging opportunities and challenges coal sector WEC-JMC 23 January 2012

This is the distribution of the coal reserves in various states Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Jharkhand and then the Madhya Pradesh. And

these are the proved, indicated, inferred and the total, and the amount of the coal that is given here. So, this is the coal reserve we are having in India, if we guess there are some variation, that may be there depending up on the source. And coal reserves in the sedimentary rocks, that the gondwana coals and the tertiary coals, this is the figure that we are getting the. This include the 450 segments and the (()) established through mapping in the northern eastern region.

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Coal Letters of Assurance (LOA)		
Sector/End use	Blocks	Geological Reserves(MT)
Power	20	2702
Iron and Steel	47	6703
Small and Isolated	2	9
Cement	3	232
Ultra Mega Power Project	7	2607
Total	79	12254

Source: Annual Report 2007-08 Ministry of Coal, GOI

Coal letters of assurance that has been given to the power, iron and steel sector, small and isolated plant, cement plant, ultra mega power projects and this is the total blocks that has been given and the letter of assurance. Coal bed methane, coal bed methane there has been an interest in the coal bed methane.

Because, coal bed methane is an environmentally friendly clean fuel similar to natural gas, preliminary activities related to exploration of the CBM in India is started in early 1990. And till 1997, the ministry of coal had allotted some coal bearing areas of the CBM exploration. As of the now, about 25 CBM reserves have been established in 5 CBM blocks, CBM gas production is about 2 lakh cubic meter per day.

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Coal Bed Methane (CBM)

- Coal bed methane is an environmentally friendly clean fuel similar to natural gas.
- Preliminary activities related to exploration of CBM in India started in early 1990's and till 1997 the Ministry of Coal had allotted some coal bearing areas for CBM exploration
- As of now about 250 BCM reserves have been established in 5 CBM blocks. CBM gas production is about 2 lakhs cubic meter per day
- [Source:Annual Report 2011-12 Govt. of India Ministry of Petroleum and Natural gas].

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Status of CBM Blocks

Block awarded	3
Under round I	5
Under round II	8
Under round III	10
Total	26
Area Awarded (sq. km)	13600
Total CBM resources (BCM)	1374
CBM Wells Drilled	210
Expected Production Potential(MMSCMD)	38
Approved Gas Sale Price(\$/MMBTU)	6.79

Sources: India Exploration and Production Activities 2007-08

This is the block awarded under the program, under round 1 exploration, round 2, round 3, total blocks 26. Area awarded, total CBM resources, CBM wells drilled these are the some of the features that is available from the ministry of coal. Types of the coal because we are having the different types of the coal and the coal is classified into various grades based on the composition calorific value and degree of the qualification that has occurred during it is formation.

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Types of Coal

- Coal is classified into various grades based on the composition and calorific value and degree of coalification that has occurred during its formation.
- Coal may be also classified as hard or soft coal, low sulphur or high sulphur coal. Coal may be also classified in rock types based on petrological components known as maceral.
- Based on maceral content coal may be classified as clarain, durain, fusain and vitrain.

[<http://www.britannica.com/EBchecked/topic/1703417/coal-classification>]

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Classification of Coal

Types of coal	Description
Peat	Peat is the precursor of coal formed
Lignite	With further increase in temperature during coal formation peat is converted to lignite. Lignite is considered as immature coal. Lignite are brown coloured, soft, low calorific value coal. It is compact in texture.
Sub-bituminous	Sub-bituminous coal are black coloured and are more homogeneous in appearance and their properties range from lignite to those bituminous coal.

Source: <http://en.wikipedia.org/wiki/coal>

One general classification of the coal that is, that is given in the form of the peat, lignite, sub-bituminous, anthracite coal like that. So, it will be discussing about the classification, general classification that is given. I will find the, peat is the precursor of

the coal formed, in the initial stage it is in the form of the peat and from conversion is taking from the peat to lignite and lignite to sub-bituminous to bituminous and then the anthracite.

So, peat is the precursor of the coal formed, lignite with the further increase in the temperature during the coal formation, peat is converted to lignite. Lignite is considered as immature coal, lignite are brownish coloured, soft, low calorific value, it is compact in texture. Sub-bituminous coal are black colour and are more homogenous in appearance and their properties range from lignite to those bituminous coal.

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Types of coal	Description
Bituminous coal	Bituminous coal is usually black, with higher carbon content and calorific value
Anthracite coal	Anthracite is highest rank coal is a harder, glassy black coal with highest content of carbon and calorific value. Anthracite coal is best suited for making metallurgical coke, for gasification to produce synthesis gas and for combustion as fuel for power generation. The ash content is low.
Graphite	Graphite is the highest rank and is difficult to ignite

Source: <http://en.wikipedia.org/wiki/coal>

Bituminous coal is the usually black with the high carbon content and calorific value, anthracite coal is highest rank coal is a harder glassy black coal and highest content of the carbon and calorific value. Anthracite coal is the best suited for making metallurgical coke, for gasification to produce synthesis gas and for combustion, as fuel for power generation. The ash content is also low, graphite is the highest rank and is the is difficult to lignite ignite sorry. This is the typical coal characteristics in selected Indian power plants compared to selected Chinese and the US.

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Typical Coal Characteristics in selected Indian Power Plants, Compared to selected Chinese and U.S. Coals

Details, %	Kahalgao n	Simhadri	Sipat	US (Ohio)	China (Long Kou)
Carbon	25.07	29.00	30.72	64.2	62.8
Hydrogen	2.95	1.88	2.30	5.0	5.6
Nitrogen	0.50	0.52	0.60	1.3	1.4
Oxygen	6.71	6.96	5.35	11.8	21.7
Moisture	18.5	15.0	15.0	2.8	11.0
Sulphur	0.17	0.25	0.40	1.8	0.9
Ash	46.0	46.0	45.0	16.0	7.7
Calorific Value, kcal/kg	2450	2800	3000	6378	6087

Source: Visuvasam et al., 2005; Ananth, 2008

Coal composition of the carbon, hydrogen, nitrogen you see the carbon content, that may be the around 25 to 62 in China. So, this is the one of the advantage in case of the China because the carbon content that is very high.

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Coal for Various Application

Selection of coal for various applications depends on its composition and carbon content, calorific value, moisture content, ash content, composition of ash, fusion temperature of ash, coking quality, sulphur content.

Selection of the coal for various application depends on it is composition and carbon content, calorific value, moisture content, ash content, composition of the ash, fusion temperature of ash, coking quality, sulphur content.

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Assessment of Coal Quality

- Coal quality plays an important role in its efficient utilization as fuel and for gasification.
- It should have high calorific value, high carbon content with low ash content, low sulphur, low moisture, low cost .
- The quality of coal depends upon its rank. The coal rank is arranged in ascending order

Lignite Sub-bituminous coal bituminous
coal → anthracite →

- Coal quality can be assessed by proximate, ultimate analysis and calorific value of the coal.

Assessment of the coal quality, coal quality plays an important role in the efficient utilization as fuel and for gasification. It should have high calorific value, high carbon content, it is low ash content, it is always desirable otherwise, the whole economy of the process that will be affected. Low sulphur content, low moisture, low cost, the quality of the coal, coal depends upon its rank. The coal rank is arranged in the ascending order as the lignite, sub-bituminous, bituminous coal and the anthracite. Coal quality can be assessed by proximate because these are the two methods, that we are using for the assessment of the coal quality, proximate and the ultimate analysis, and the calorific value.

Proximate analysis involves the determination of the moisture, volatile matter, ash and the fixed carbon, ultimate analysis involves determination of the carbon and hydrogen nitrogen, sulphur, oxygen. Calorific value, the lower calorific value, high calorific value these are the or gross calorific value, these are the some of the measurement of the calorific value and then the useful heating value. Coal as the fuel because the as I told you earlier also, major portion of the coal we are using as a fuel and the for the power generation. But, fuel coal, other routes are also available, that coal can be used as a liquid fuel also.

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- **Proximate analysis** involves determination of moisture, volatile matter, ash and fixed carbon.
 - **Ultimate analysis** involves determination of carbon and hydrogen, nitrogen, sulphur, oxygen.
- Calorific value is represented as Higher calorific value (HCV) or Gross calorific value (GCV) and Lower calorific value (LCV) or Net calorific value (NCV).
- **Useful heating value (UHV)**. UHV is defined as $\text{UHV kcal/kg} = [8900 - 138 \times (\text{percentage of ash content} + \text{percentage of moisture content})]$

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Coal as Fuel

- Coal accounts for 53% of the commercial energy sources in India which is high compared to the world average of 30%.
- The 11th plan projected India's coal demand to grow at 9.7% per annum against 5.7% during 10th plan almost two fold increase.
- The commercial coal in India is mainly consumed by the power (72%), Steel (14%), cement (9%) and others 9%.

Coal accounts for the 53 percent of the commercial energy sources in India, which is high compared to the world average of 30 percent. The 11th plan projected India's coal demand to grow at 9.7 percent per annum against 5.7 percent during the 10th plan, almost two fold increase. The commercial coal in India is mainly consumed by the power sector, steel sector and cement so, you can say, the major share is the power plants, steel plant and the cement.

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Allocation of Coal Blocks to Private Companies

Sector/End use	Blocks	Geological Reserves(MT)
Power	20	2702
Iron and Steel	47	6703
Small and Isolated	2	9
Cement	3	232
Ultra Mega Power Project	7	2607
Total	79	12254

Allocation of the coal blocks to the private companies for the power sector, 20 blocks iron and steel, small and isolated cement plants and ultra mega power projects. Now, we will be discussing about the coal, as a chemical feed stock, why the importance of the coal as the chemical feed stock. Because, you see the all the coal originally was utilized as a fuel for the production of the gasses, you must be knowing about the producer gas, town gas, blue gas these were the some of the, through the gasification route that was been used.

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Coal as Chemical Feed Stock

- Coal originally was utilized as fuel.
- Many of the petrochemicals now derived from petroleum and natural gas was earlier derived from coal
- With starting of coke oven plants it became source of organic and some inorganic chemicals.
- Coal tar from coke-oven plants continues to be a source of aromatics, naphthalene and other valuable aromatics like pyridine, picoline, quinolene.

Many of the petrochemicals now, derived from the petroleum and natural gas was earlier derived from the coal and especially from the coke oven plants, because the aromatics earlier benzene, toluene, xylene, the aromatics and a large number of the organic chemicals are present in the coke oven gases. Today, we are getting either through the coal tar distillation or the separation of the benzyl so, these are the that of the importance source of the aromatics. During this, only thing that in case of the coke oven plant, the yield of the aromatics that is compatibly low.

With the starting of the coke oven plants, it becomes source of organic and some inorganic chemicals because during the the coke oven plants or the coke oven gases, they also contain the ammonia and that ammonia that is being utilized by steel plant for making of the either ammonium sulphate or the ammonium nitrate. coal tar from the coke oven plants continues to be the source of aromatics, naphthalene and other valuable aromatics like pyridine, picoline, quinolene this is the one of the selected list, the important actually the aromatic. Apart from this, large number of aromatics are present in the from the coal tar, that we are getting in the from the coke oven plant.

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Coal as Chemical Feed Stock

- Before the coming of petrochemical production a large number of organic chemicals were produced from acetylene produced from calcium carbide route in which coal was a important feed.
- China has come in a big way for production of chemicals from coal because of the huge coal reserves.
- With the rising cost of crude oil and dwindling crude oil reserves, coal has again received attention all over the world to utilize coal as an alternative source of chemical feed stock.

Before coming of the petrochemical production, a large number of the organic chemicals were produced from the acetylene, produced from the calcium carbide route, in which coal was a important feed stock. China is come in a big way for production of

the chemicals from the coal, because of the huge coal reserves and the better quality of the coal they are having.

With the rising cost of the crude oil and dwindling crude oil reserves, coal has again received attention all over the world to utilize coal as an alternative source of chemical feed stock, not only in the developing country, in the developed country. But also, in India, we are working to utilize the coal for the production of the chemicals through the gasification route.

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Various Routes for Production of Organic and Inorganic Chemicals from Coal

- Coal carbonization and coal tar distillation
- Coal gasification and use of synthesis gas as feed stock for ammonia production
- Coal liquefaction by hydrogenation
- Acetylene calcium carbide (from Coal and Lime stone

Various routes for the production of the organic and inorganic chemicals, coal carbonization and the coal tar distillation, coal gasification and use of synthesis gas as feed stock for ammonia production, coal liquefaction by hydrogenation, acetylene from the calcium carbide.

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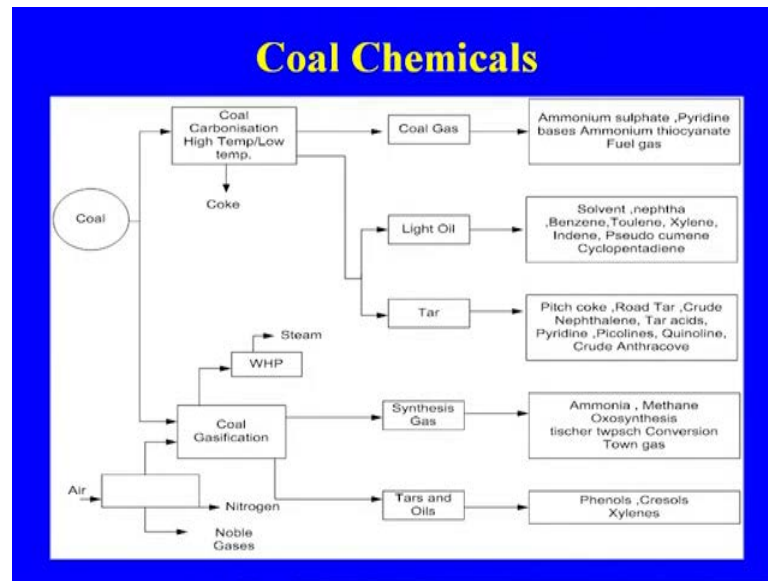
Routes For Production Of Organic And Inorganic Chemicals From Coal

- Coal to methanol technology
- Coal to olefin technology
- Coal to plastic technology
- Acetylene from calcium carbide made from lime and coal and various Chemicals from Acetylene

These are some of the technologies, which have come during the recent years and are getting importance in the utilization of coal. That is, the coal-to-methanol technology. Because, that is the intermediate, this is also of course, the production of synthesis gas and from the synthesis gas to methanol. Coal-to-olefin technology because the methanol-to-olefin technology or coal-to-olefin technology because again it is from the coal to methanol and methanol to olefin.

Coal-to-plastic, this is also from the coal-to-olefin, these olefins are being used for the making of plastic. Already, China they are going to have a plant based on coal for the production of plastic, acetylene from calcium carbide made from lime and coal and various chemicals from the acetylene. We are getting a large number of chemicals from the acetylene, which were earlier manufactured from petrochemical. Now, you see this is the various processes involved and what are the actual products we are getting and the various coal chemicals, a long list is there.

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Coal, coal carbonization, high temperature, low temperature carbonization because two types of the carbonization were taking and we are getting the coke and the gases, and the coal tar that we are using for the production of the your various actually, the inorganic and organic compound. Ammonium sulphate that is one of the very important part of the any steel making plant, because in many of the steel plant, they are making the ammonium sulphate or ammonium nitrate.

Pyridine base ammonium thiocyanate fuel gas then the solvent naphtha, benzene, toluene, xylene, indene, all this actually cyclopentadiene from the light oil or from tar, pitch coke, road tar, crude naphthalene because naphthalene earlier it was the route for making of the phthalic anhydride. Now, we are making the phthalic anhydride through the orthoxylene route and then the coal gasification of course, the synthesis gas and through the synthesis gas, ammonia, methanol, oxosynthesis, Fischer Tropsch synthesis conversion, tar and oils for the phenols and the cresols. Coal based fertilizer plant because as I told you, the coal that has been a very important source for this manufacture of the synthesis gas.

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Coal Based Fertiliser Plant

- Coal Gasification and Use of Synthesis Gas as Feed Stock for Production of ammonia has again received attention
- Partial oxidation of coal is used for production of synthesis and ammonia. CO from partial oxidation is converted to CO₂ which is used for Urea manufacture .
- Synthesis gas CO+H₂ is used as chemical feed stock for production of large number chemicals.

And the coal gasification and use of the synthesis gas, as feed stock for production of the ammonia has again received attention. Because, two units we were having earlier, when we started the manufacture of the ammonia and the urea at the our Ramagundam and the Talci plant of the FCI, which was later on closed, because of the because large number of the fertilizer plant they came based on the natural gas or the naphtha, and they were more economical.

So, partial oxidation of the coal is used for production of synthesis gas and ammonia CO from the partial oxidation is converted to CO₂, which is used for the urea manufacture. That is the process, we are using in case of the ammonia manufacture and the urea manufacture, synthesis gas is used as chemical feed stock for production of large number of the chemicals. Coal gasification that has become one of the important source for producing fuel and the synthesis gas.

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Coal Gasification

- Coal gasification and production of fuel from FT process getting significant attention .
- Coal gasification and production of synthesis gas is now considered to be a major potential on- purpose source of commodity petrochemicals.

Coal gasification, production of the fuel from Fischer Tropsch synthesis getting significant attention during recent years. Coal gasification and production of synthesis gas is now, considered to be a major potential on purpose source of commodity. Petrochemicals, which are now being produced through the crude oil route or from the petroleum base.

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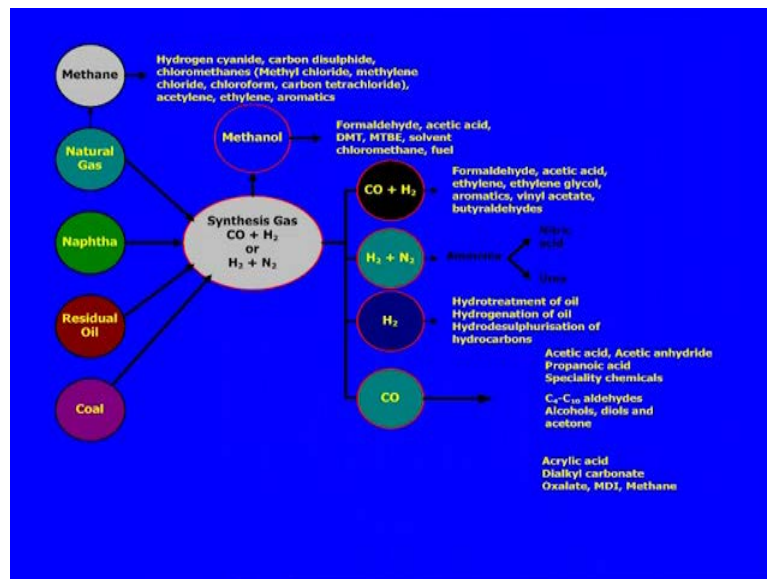
Coal Gasification

- The cost of coal and higher cost of chemicals derived from coal has been major constrain in its utilization as a substitute for petroleum and natural gas.

Coal gasification, the cost of the coal and higher cost of the chemicals derived from the coal has been major constrain in it is utilization, as a substitute of the petroleum and

natural gas, because the synthesis gas, which we are getting from the naphtha or the natural gas is much cheaper. Even the product cost of production if you compare, the fertilizer plant which is based on the coal and the fertilizer plant based on the natural gas that is, the cost it is more in case of the coal than the natural gas. It is just in the descending order if you take the natural gas then naphtha then the coal so, the much higher cost of production is there in case of the coal. And especially, in Indian condition because of the high ash content, that is also one of the reason for the high cost.

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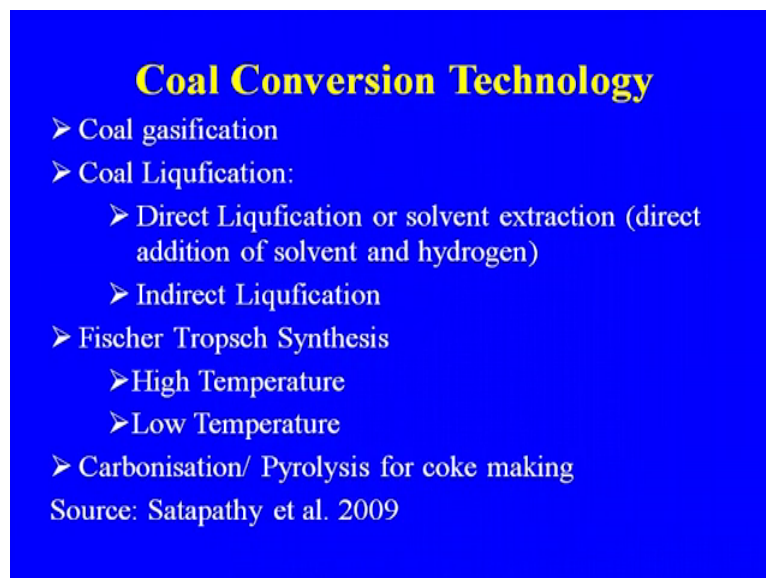
This is in brief about the actually the various products, which we are getting from the synthesis gas and so, the methane, natural gas and naphtha you have seen. But, one source from the coal, you see from the coal because this actually the various product from the synthesis gas that we will be discussing, while discussing about the petro chemical processes in the synthesis gas and the chemical. But, in brief here, just you can see the from the coal gasification route, you will be getting the synthesis gas and from the synthesis gas, a large number of the product chemicals that can be generated.

That is, the methanol, methanol to formaldehyde, acetic acid, dimethyltryptamine, MTBE, solvent, chloromethane, fuel because the methanol blend that can be also there. Now, the methanol is coming in a big big way in the as a fuel shell, the production of the CO and H₂ that is the raw material for the formaldehyde, acetic acid, ethylene.

Hydrogen and nitrogen, again this is also called sometimes synthesis gas and this is for the production of the ammonia and the urea.

Hydrogen, that you can separate from the CO₂ after conversion of the CO₂, and that CO₂ that is being used in the fertilizer plant and that will be, sometime it is creating problem gasification or the when in case of the stock. So, during the production of the hydrogen, about 10 tonnes of the CO₂ is also produced. If you are not having the use of the CO₂ in the process then that will create problem, CO based on the CO, these are the some of the chemicals. Acetic acid, acetic anhydride, propanoic acid, acrylic acid these are the some of the major actually, the chemicals which are producing from the CO or the synthesis gas.

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Coal Conversion Technology

- Coal gasification
- Coal Liquefaction:
 - Direct Liquefaction or solvent extraction (direct addition of solvent and hydrogen)
 - Indirect Liquefaction
- Fischer Tropsch Synthesis
 - High Temperature
 - Low Temperature
- Carbonisation/ Pyrolysis for coke making

Source: Satapathy et al. 2009

Coal conversion technology coal gasification, coal liquefaction, that may be direct liquefaction or the solvent extraction where the, we are adding the solvent and hydrogen, indirect liquefaction. Fischer Tropsch synthesis, that may be again high temperature and low temperature, carbonisation pyrolysis of the for coke making. As I told you earlier also, that the calcium carbide and acetylene that was the major source of making many of the chemicals or now, we called the petro chemical.

Because, there was no petro chemical if you see the, when we started the petro chemical refinery it was in the beginning of the 19th century, it was the 1920, that some of the petro chemical we recovered from the refining. So, earlier before coming of the petro

chemical complex, it was the calcium carbide and from the calcium carbide to acetylene and acetylene that was been used for the manufacture of large number of the chemical.

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Calcium Carbide and Acetylene

- Calcium carbide is produced industrially in an electric arc furnace from a mixture of lime and coke at approximately 2000 °C. This method has not changed since its invention in 1888
- $\text{CaO} + 3 \text{C} \rightarrow \text{CaC}_2 + \text{CO}$
- Calcium carbide react with water and produce acetylene which was major source of chemicals before coming of the petrochemicals
- $\text{CaC}_2 + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_2 + \text{CaO}$

So, this is the process, how the calcium carbide and calcium carbide to acetylene production is there from after adding of the water, you are producing acetylene and the CO again we are regenerating.

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Product from Acetylene

- Vinyl chloride, Polyvinyl chloride
- Acrylonitrile, Acrylic fibre
- Vinyl alcohol
- Vinyl fluoride, Vinylidene Chloride
- Acrylic acid, methyl methacrylate
- Acetaldehyde
- Vinyl ethers
- 1,4 Butadiene
- Chloroprene
- Chlorinated solvents

These are the some of the product we are getting from the acetylene, vinyl chloride polyvinyl chloride, acrylonitrile, acrylic fibre because earlier when the cracker plant was

not there, because now we are making the vinyl chloride from the ethylene, which we are getting from the cracker plant. Earlier, it was the vinyl chloride from the acetylene route that was being used for the polyvinyl chloride. And now, still one plant Sriram chemicals and fertilizer at Kota in India, they are using the acetylene route for production of the vinyl chloride and polyvinyl chloride.

Acrylic fibre again, acrylic fibre was because acrylonitrile that was made from the acrylic route and so, the acrylonitrile produced from the acrylic, that was been used earlier for the acrylic fibre. But now, acrylonitrile we are having with the coming of the propylene, now we are making to the petro chemical. Vinyl alcohol, vinyl fluoride, vinylidene chloride, acrylic acid, methyl metha acrylate, acetaldehyde, acetaldehyde again because normally, we are making through the ethylene or the alcohol route but earlier it was through the acetylene route, technology available. Vinyl ethers, 1 4 butadiene or chloreprene, for the chloreprene also the acetylene route is available, chlorinated solvents.

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Coal to Methanol Technology

- The process involves the production of synthesis gas from coal via partial oxidation followed by conversion of synthesis gas to methanol.

Coal to methanol technology, the process involves the production of synthesis gas from coal via partial oxidation followed by conversion of the synthesis gas to methanol, this is the technology that is been used for the production of the methanol. Again we will be discussing in detail about the production of the methanol from the synthesis gas, while discussing about the petro chemicals in module 6, module 7 sorry.

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Coal to Olefin Technology

- Methanol from synthesis gas (from coal gasification) can be converted to dimethyl ether (using bifunction catalyst) which can be used as a gasoline blend
- Methanol can be converted to olefin by MTO: this produces Ethylene and propylene
- Olefin synthesis from syngas via dimethyl ether to olefin process [SDTO]

Coal to olefin technology, methanol from synthesis gas from coal gasification can be converted to dimethyl ether using bifunction catalyst, which can be used as a gasoline blend or methanol can be converted to olefin by MTO process. This process produces ethylene and propylene, olefin synthesis from synthesis gas via dimethyl ether to olefin process, that is also SDTO that is also available.

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Coal to Plastic Technology

- Olefin produced from the coal route can be used for the manufacture of Polyolefins plastic.
- Propylene can be manufactured from Methanol to olefin (MTO) technology
- Propylene from MTO can be used for Polypropylene
- Coal to plastic technology based on coal is getting importance
- China is already going to have one commercial plant

Olefin produced from the coal route can be used for the manufacture of polyolefins and that is the polyolefin. Plastic propylene can be manufactured from methanol to olefin

technology, propylene from MTO can be used for polypropylene, coal to plastic technology based on coal is getting importance. China is already going to have one commercial plant for making polyethylene and the polypropylene from the coal route. Major constrain in coal to chemical route, variation in the coal quality, which affect the efficiencies and the economics of the gasification, changes in the syngas composition due to variation of the coal quality.

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Major Constrain in Coal to Chemical Route

- Variation in coal quality which affect the efficiencies and economics of gasification
- Changes in the syngas composition due to variation coal quality
- High ash content of coal as in case of India
- High sulphur Content
- Impurities present in coal may be detrimental as they may affect the catalyst and the process
- Environmental consideration such as Sulphur content and CO₂ sequestration. mercury emission

Because you see coal quality that is varying very widely from one place to another from one source to another source. And so quality even the, just you take the case of Assam coal, although it is having high carbon but very high sulphur content is there, some of the coal are having very high ash content. So, changes in the syngas composition due to variation in the coal quality is there, high ash content of the coal as in case of the India, high sulphur content. Impurities present in the coal may be determined determined till, as they may affect the catalyst and the process because the catalyst poisoning there, may be there because of the some of the impurities which are present in the coal.

Environmental consideration such as sulphur content and CO₂ emission, which is there in case of the your coal gasification route. Mercury emission that is one of the another problem, that we are having in case of the coal because some of the coal they are having the high mercury and so, because of the mercury emission. Now, that has been made mandatory for all the thermal power plant to monitor the mercury content of the coal.

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So, this was about the coal and the coal as the chemical feed stock in the lecture 2 of the module 2. We will be discussing about the coke oven plant because that was the starting of the production of the chemicals, which now we are seeing through the petro chemical route.