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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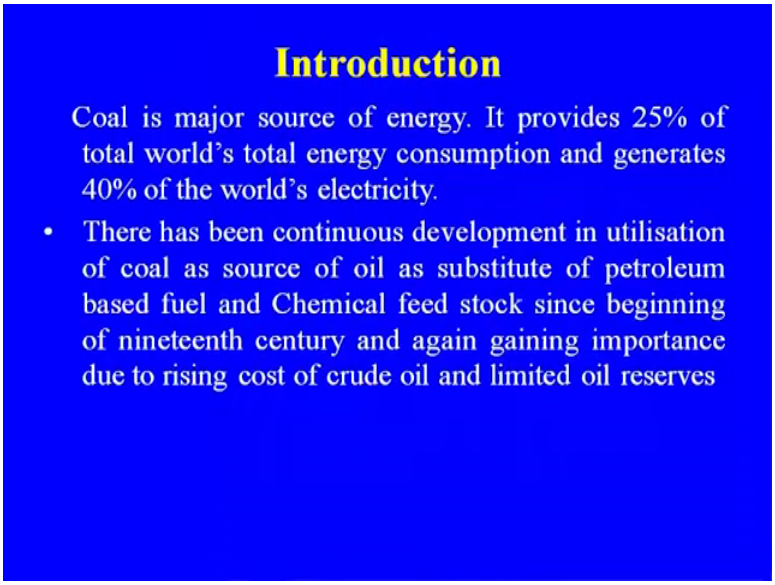

As you know, the coal is the major source of energy; it provides 25 percent of the total world energy consumption and generates 40 percent of the world's electricity. There has been continuous development in utilisation of coal, as source of oil as substitute of petroleum based fuel and chemical feed 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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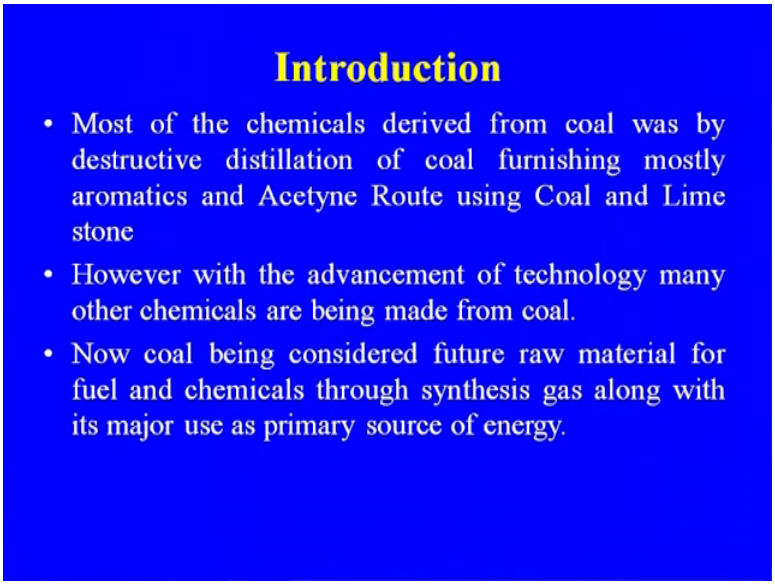

Most of the chemicals derived from the coal was by destructive distillation of coal, furnishing mostly aromatic and acetyne route using coal and lime stone. However, with the advancement of technology, many other chemicals are being made from the coal. Now, coal being considered future raw material for 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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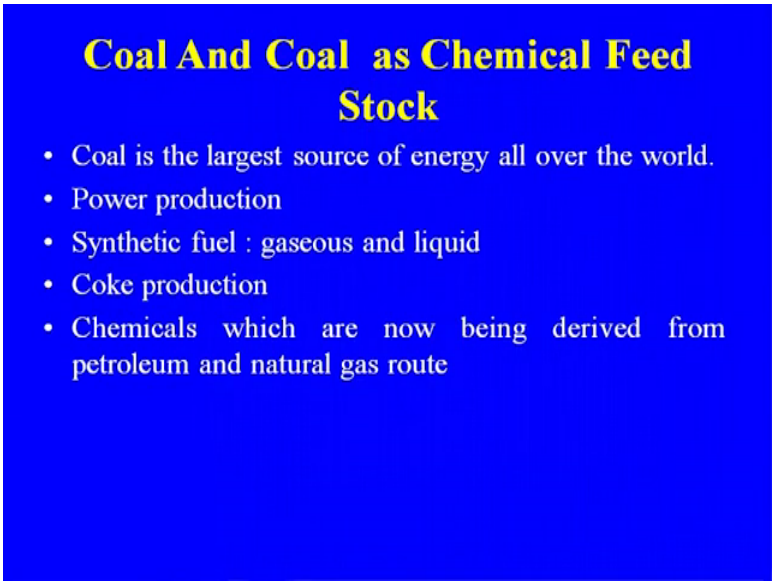

As I discussed earlier, the Coal is the largest source of energy all over the world and the power production. But, the other routes where, we are using the coal, that is the synthetic fuel that may be in the form of the gaseous liquid. Coke production that in the coke oven plant, where we are producing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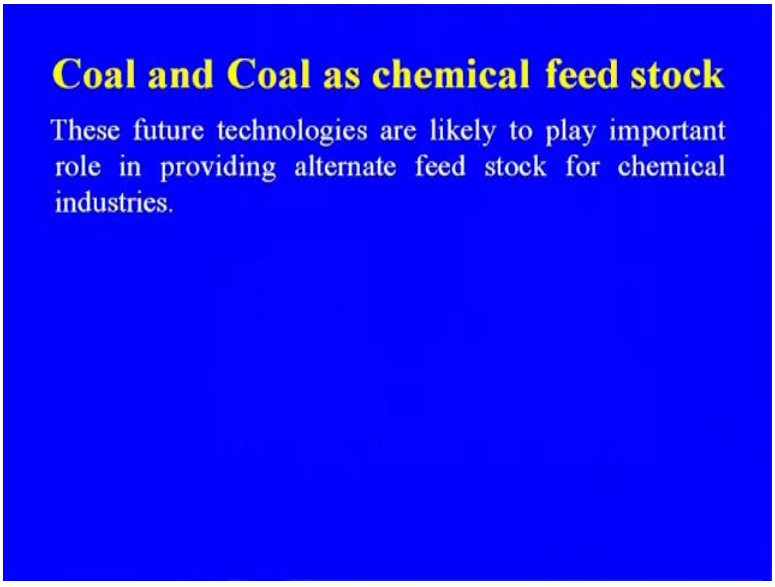

Coal to dimethyl ether through the methanol route, that is also getting important because dimethyl ether that can be directly blend with the gasoline. Coal to plastic through the methanol to olefin technology, because the during the process, we will produce the propylene and propylene to plastic are 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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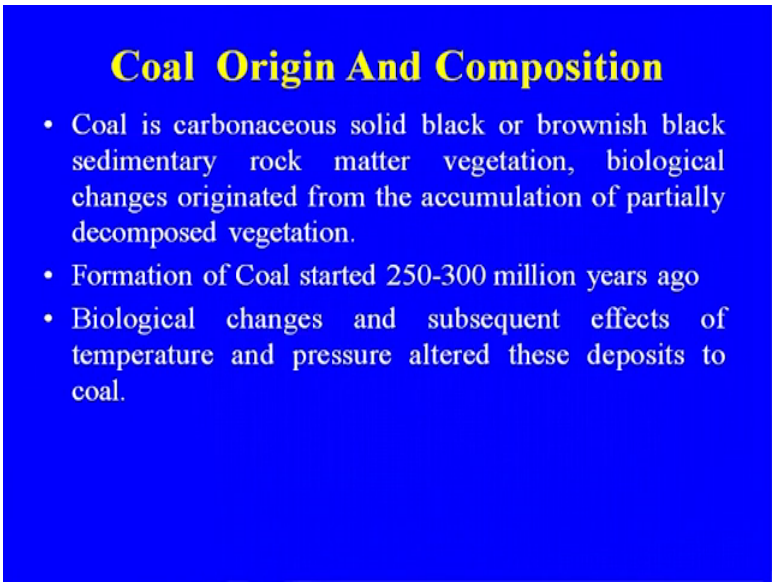

Coal is the carbonaceous solid black or the brownish black sedimentary rock, matter vegetation, biological changes originated from the accumulation of the partially decomposed vegetation. Formation of the coal is started 250 to 300 millions years ago and that had taken long time, in the coal which you 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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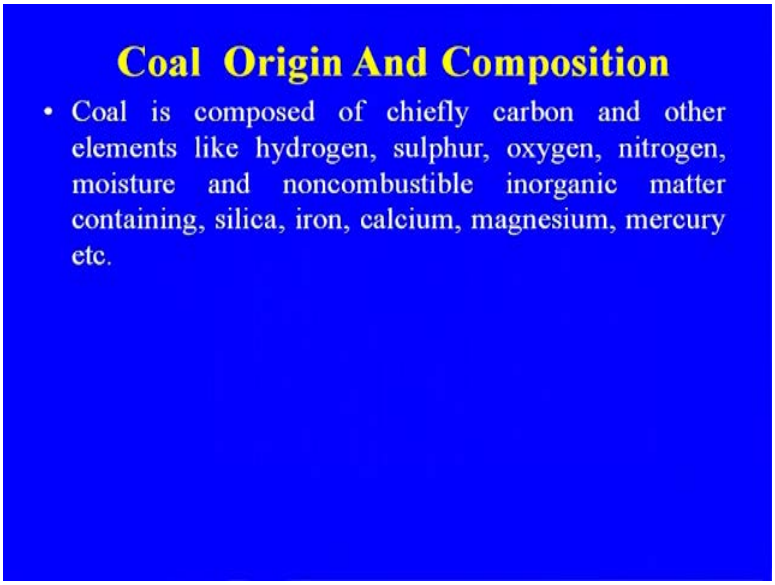

Coal is composed of chiefly the carbon and other elements like hydrogen, sulphur, oxygen, nitrogen, moisture and non combustible inorganic matter containing silica, iron, calcium, magnesium and mercury. Mercury now again a rear the problem of mercury machine that was not there form the thermal power 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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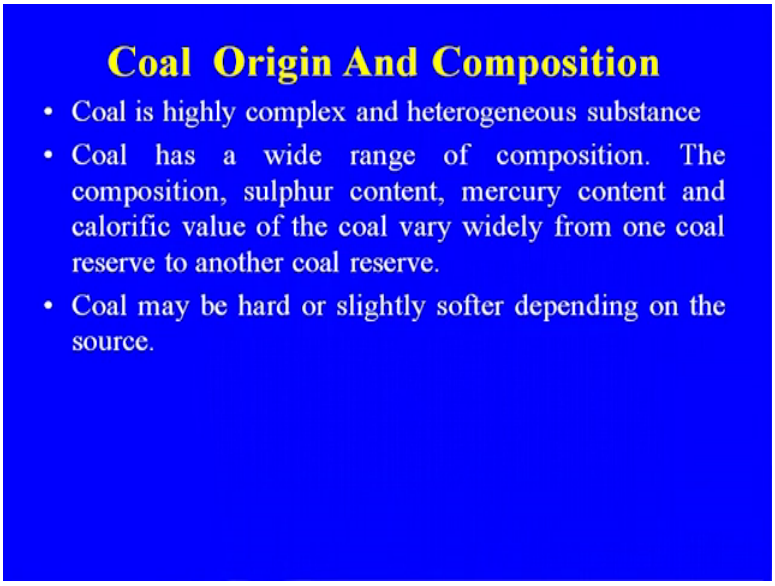

Coal is highly complex and heterogeneous substance, coal has a wide range of composition, the composition is sulphur content, mercury content, calorific value of the coal vary widely from one coal reserve to another coal reserve. Coal may he hard or slightly softer depending upon the source, Assam coal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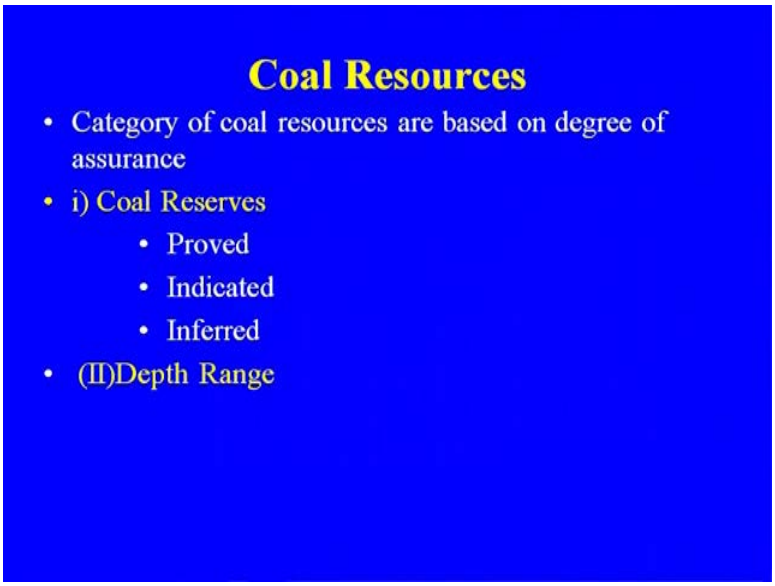

Coal resources, category of the coal resources are based on the degree of assurance that is, the coal reserve, proved reserve, indicated inferred or the depth range. So, these are two basis for the categorization of the coal resources, let us discuss the definition of the proved reserve or indicated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

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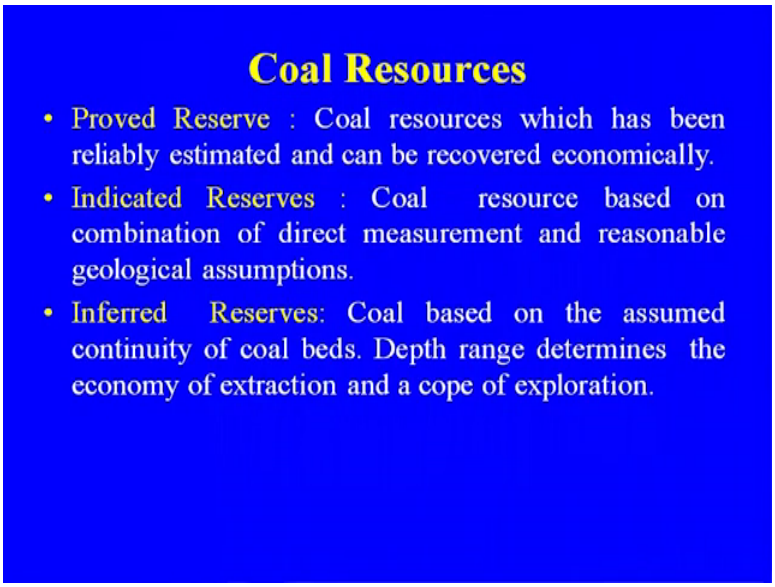

So, proved reserve the coal resource, which has been reliably estimated and can be recovered economically so, that we called, that is coming in the category of the proved reserve. Indicted reserve means, coal resource based on the combination of direct measurement and reasonable geological assumption. 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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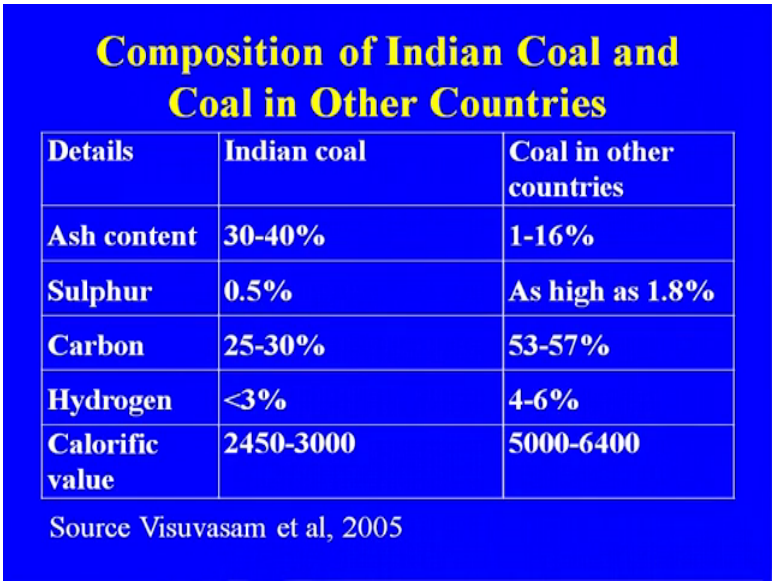

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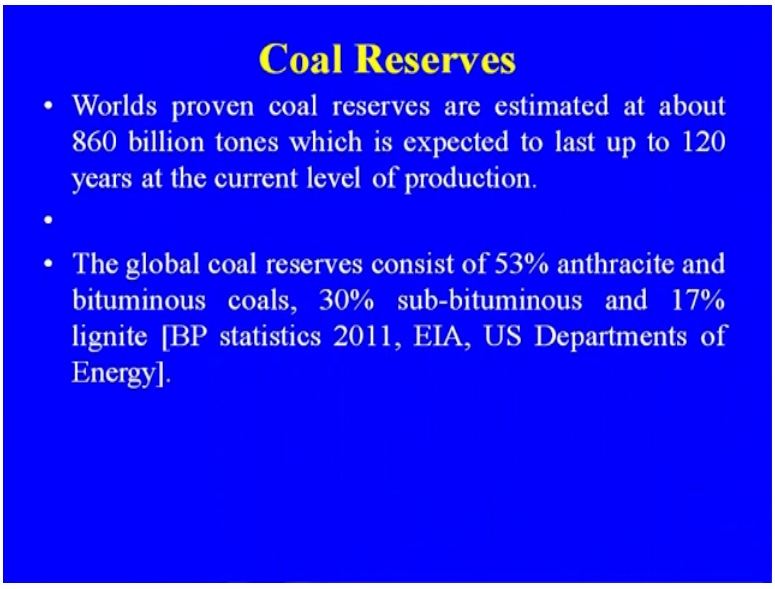

Coal reserve, worlds proven coal reserves are estimated at about 860 million billion tones, which is expected to last for about 120 years at the current level of production and utilization. The global coal reserves consists of 53 percent anthracite and bituminous coal, 30 percent sub-bituminous coal, 17 percent of lignite. Largest coal reserves of coal are in China, USA, Russia, Australia and India, India has the 5 th 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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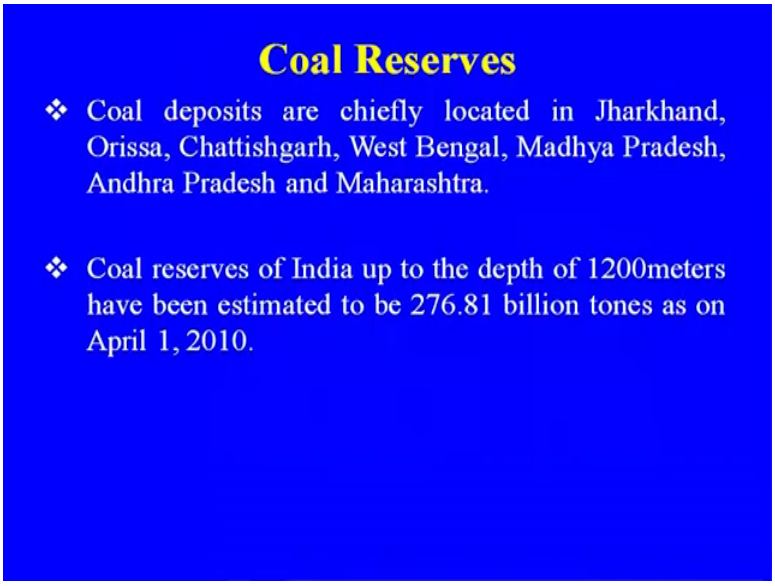

Coal deposits are chiefly located in Jharkhand, Orissa, Chhattisgarh, West Bengal, Madhya Pradesh, Andhra Pradesh and Maharashtra. In India, coal reserves from India upto the depth of 1200 meters have been, that is not 1200, 120 meters have been estimated to be 276.81 billion tones as on April 1, 2010.

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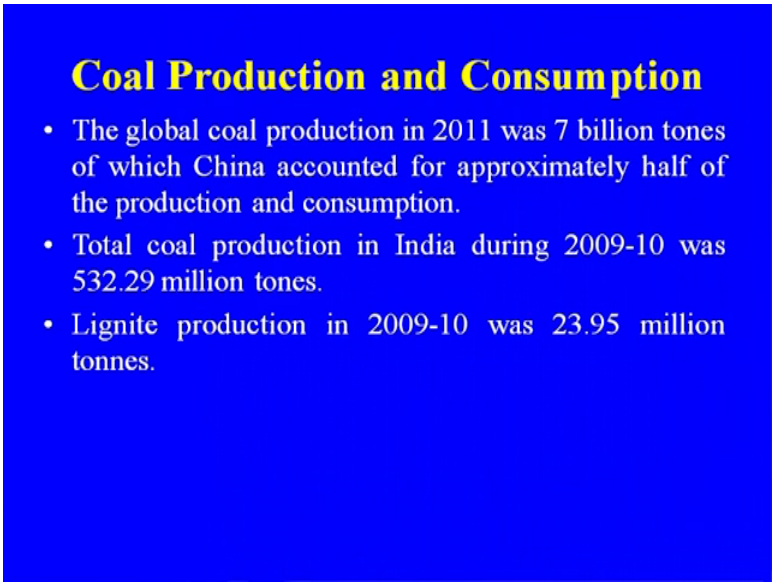

The global coal production in 2011 was 7 billion tonnes, of which china accounted for approximately half of the production and consumption. And this is the reason, how the now the coal in china that is been also used for the production became. Total coal

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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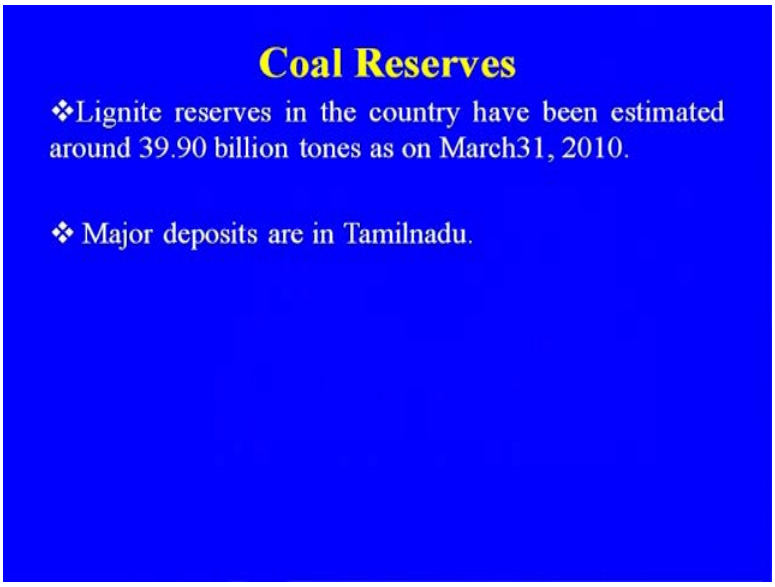

Lignite reserves in the country have been estimated around 39.9 billion tonnes as on March 31 st, 2010 and major deposits are in Tamil Nadu. In Tamil Nadu, some of the plants are there, which are using the lignite as a source of power and as the source of chemical.

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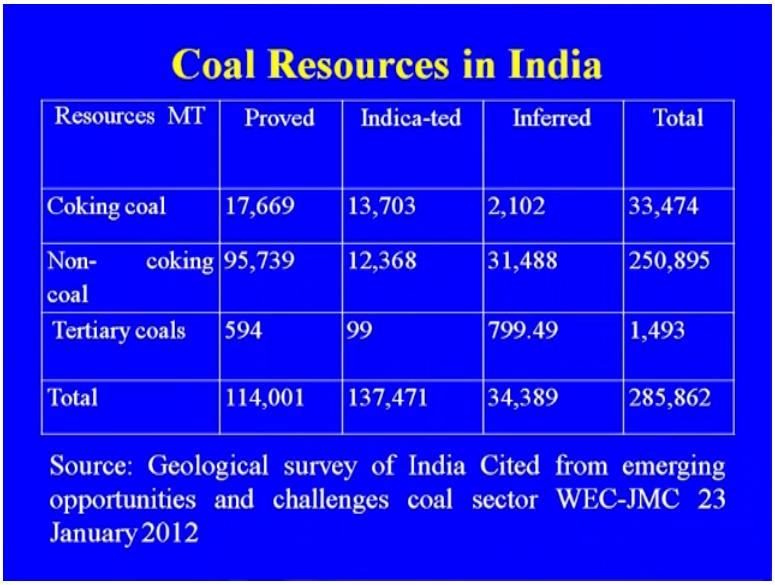

This is the status of the coal reserve in India coking coal, non coking coal, tertiary coal and the total coal that is the proved, indicated, inferred.

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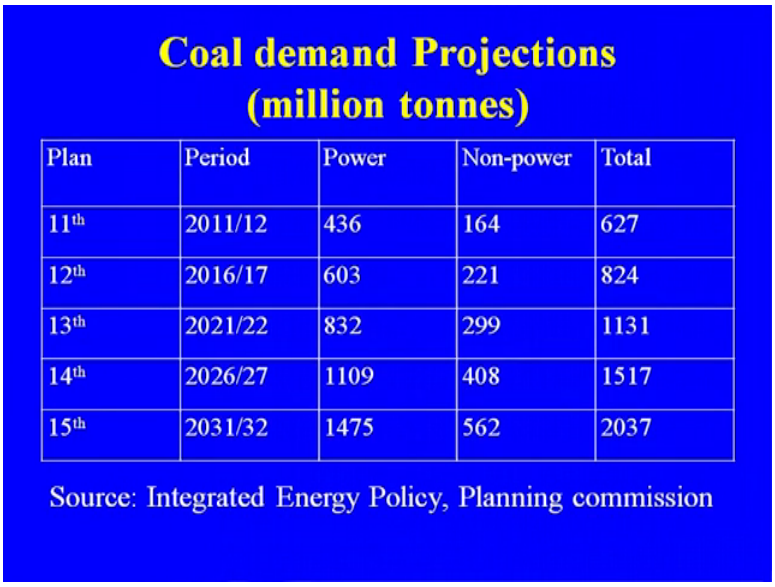

Coal demand projection in the 11 th, 12 th, 13 th, 14 th, 15 th plan, these are the some of the figures that is available. And so, you can get an idea about the, what is the coal demand during the next few years.

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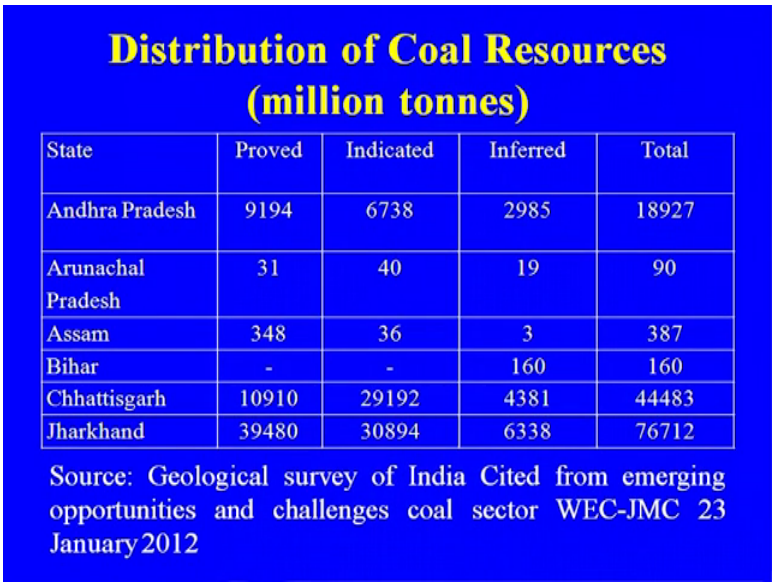

This is the distribution of the coal reserves in various states Andhra Pardesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Jharkhand and then the Madhya Pradesh. And

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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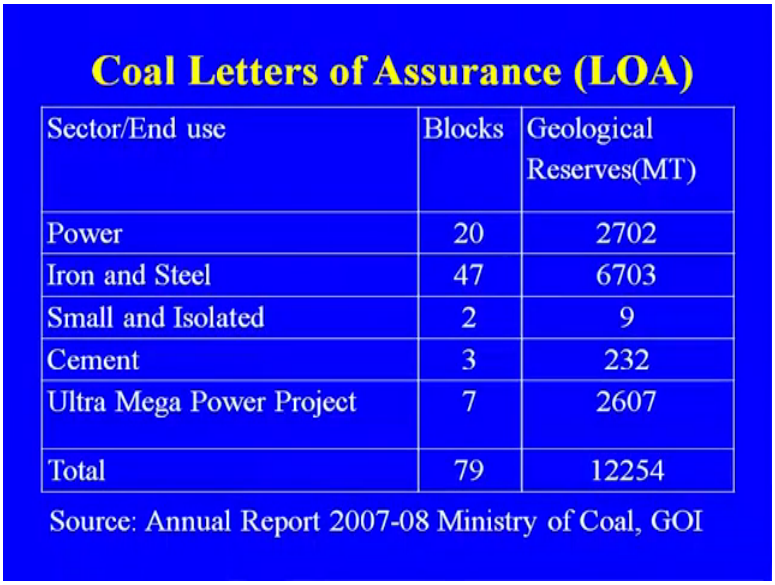

Coal letters of assurance that has been given to the power, iron and steel sector, small and isolated plant, cement plant, ultra mega power projects and this is the total blocks that has been given and the letter of assurance. Coal bed methane, coal bed methane there has been an interest in the coal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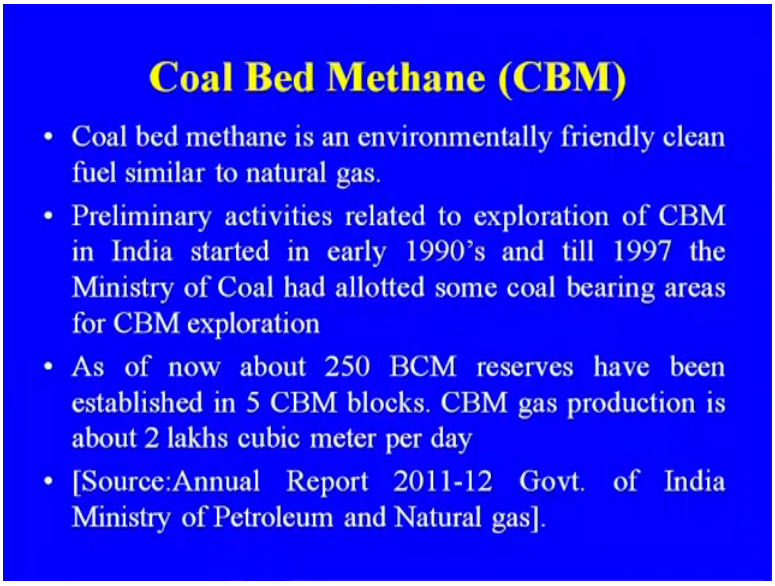

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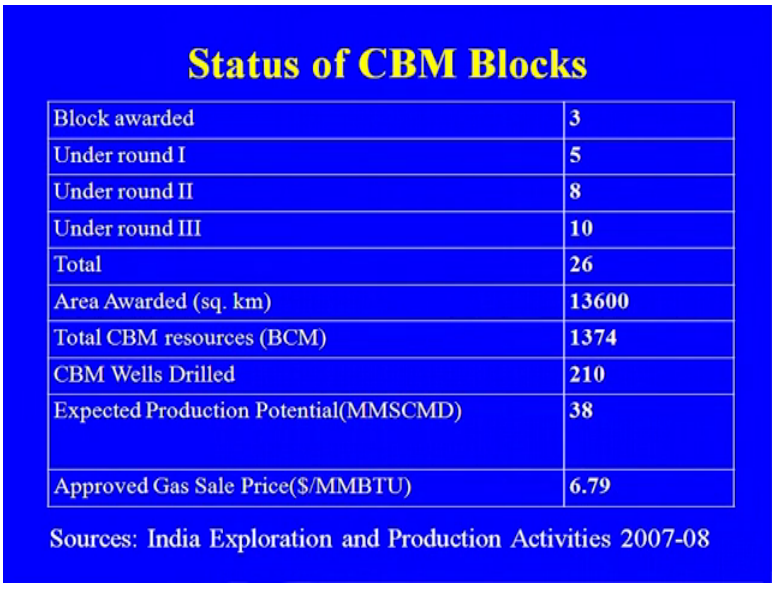

This is the block awarded under the program, under round 1 exploration, round 2, round 3, total blocks 26. Area awarded, total CBM resources, CBM wells drilled these are the some of the features that is available from the ministry of coal. Types of the coal because we are having the different types of 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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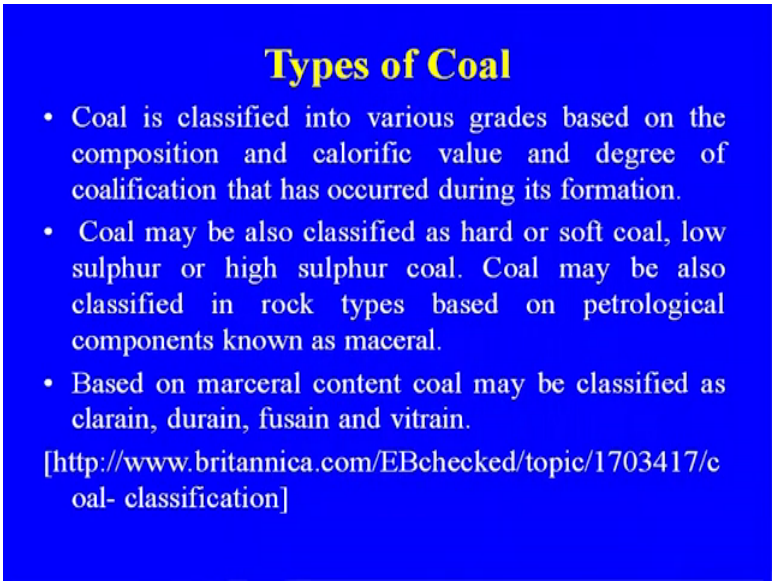

Coal may be also classified as hard or soft coal, low sulphur high sulphur coal, coal may be also classified in rock types based on the petrological components known as maceral. Based on the maceral content, coal may be classified clarain, durain, fusain and the vitrain.

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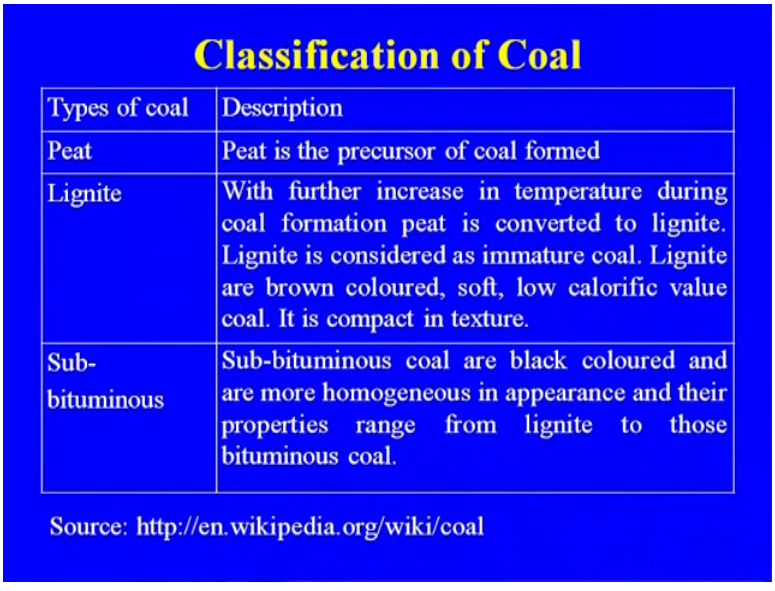

One general classification of the coal that is, that is given in the form of the peat, lignite, sub-bituminous, anthracite coal like that. So, it will be discussing about the classification, general classification that is given. I will find the, peat is the precursor of

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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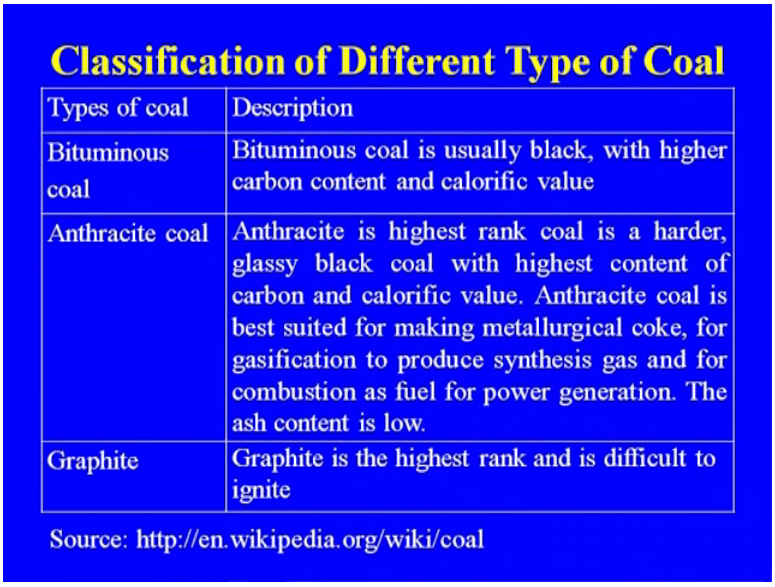

Bituminous coal is the usually black with the high carbon content and calorific value, anthracite coal is highest rank coal is a harder glassy black coal and highest content of the carbon and calorific value. Anthracite coal is the best suited for making metallurgical coke, for gasification to produce 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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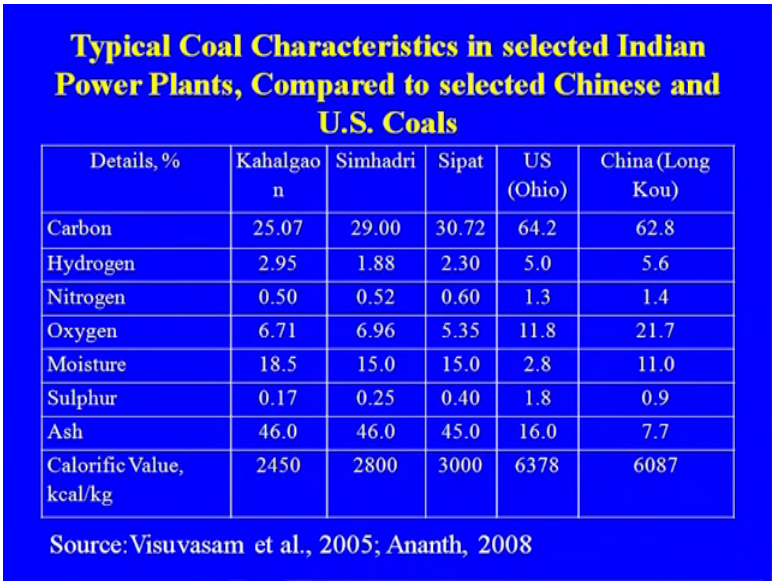

Coal composition of the carbon, hydrogen, nitrogen you see the carbon content, that may be the around 25 to 62 in China. So, this is the one of the advantage in case of the China because the carbon content that is very high.

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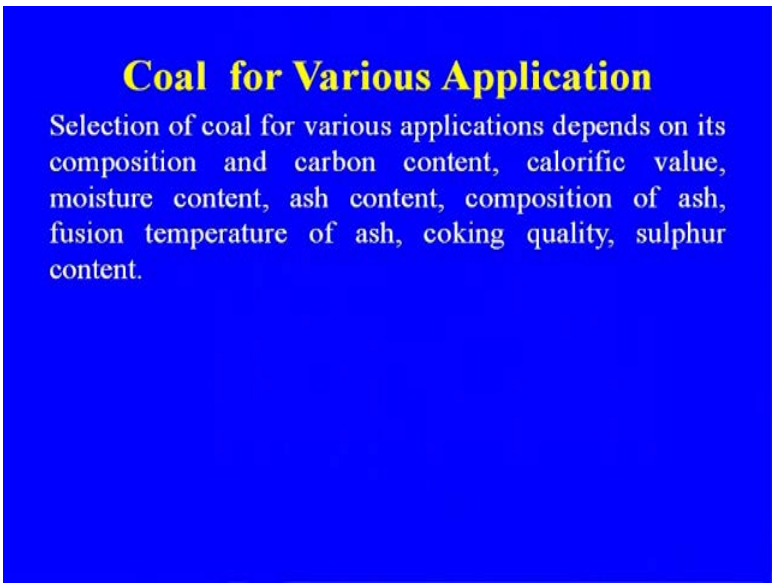

Selection of the coal for various application depends on it is composition and carbon content, calorific value, moisture content, ash content, composition of the ash, fusion temperature of ash, coking quality, sulphur content.

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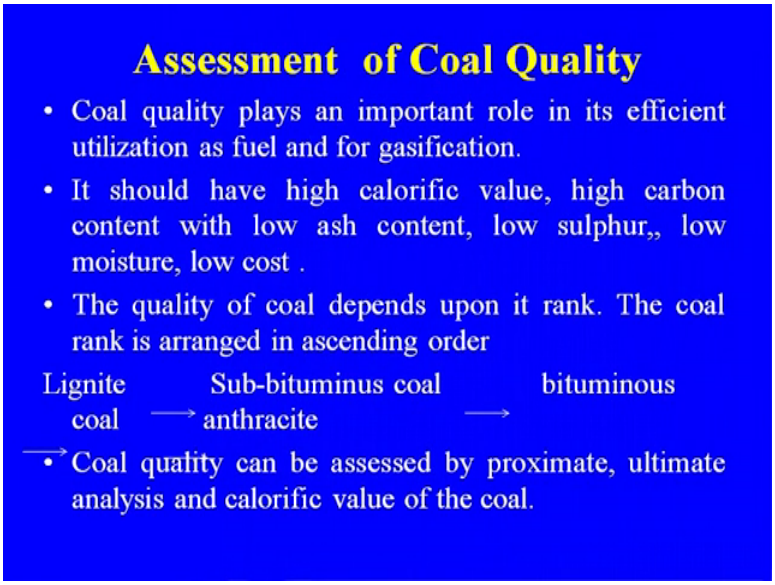

Assessment of the coal quality, coal quality plays an important role in the efficient utilization as fuel and for gasification. It should have high calorific value, high carbon content, it is low ash content, it is always desirable otherwise, the whole economy of the process that will be affected. Low sulphur content, low moisture, low cost, the quality of the coal, coal depends upon it is rank. The coal rank is arrange 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 involve 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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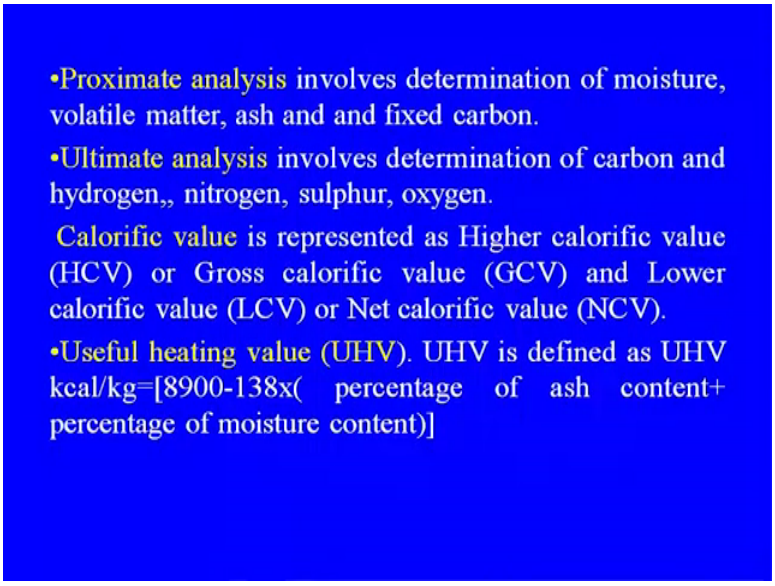

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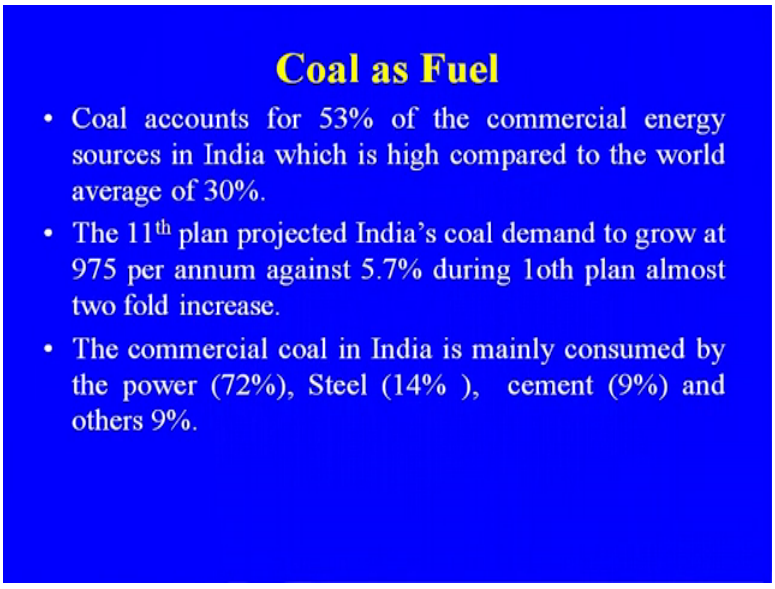

Coal accounts for the 53 percent of the commercial energy sources in India, which is high compared to the world average of 30 percent. The 11 th plan projected India's coal demand to grow at 97 percent per annum against 5.7 percent during the 10 th plan, almost two fold increase. The commercial coal 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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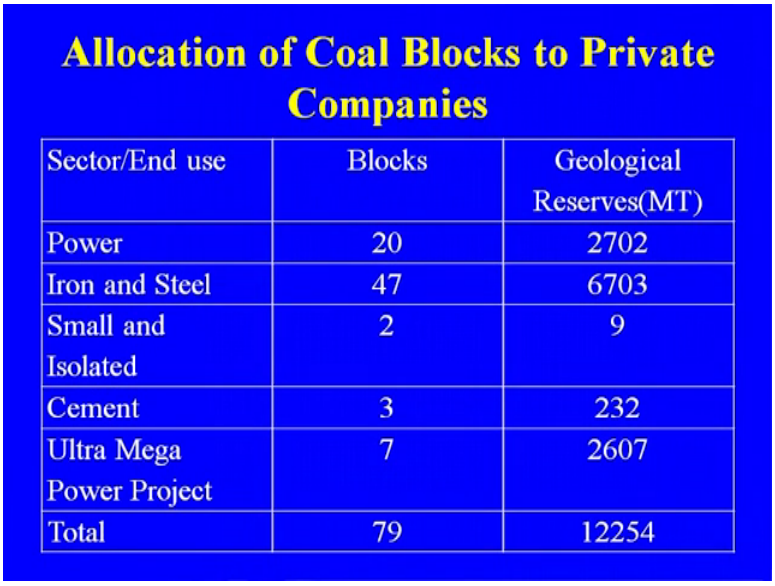

Allocation of the coal blocks to the private companies for the power sector, 20 blocks iron and steel, small and isolated cement plants and ultra mega power projects. Now, we will be discussing about the coal, as a chemical feed stock, why the importance of the coal as the chemical feed stock. Because, 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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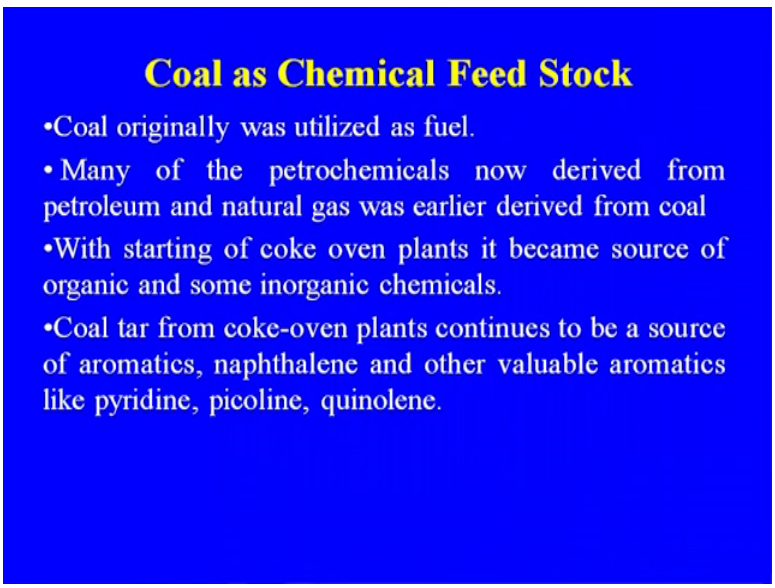

Many of the petro chemicals now, derived from the petroleum and natural gas was earlier derived from the coal and especially. from the coke oven plants, because the aromatics earlier benzene, toluene, xylene, the aromatics and a large number of the organic chemicals are present in in the coke oven gases. 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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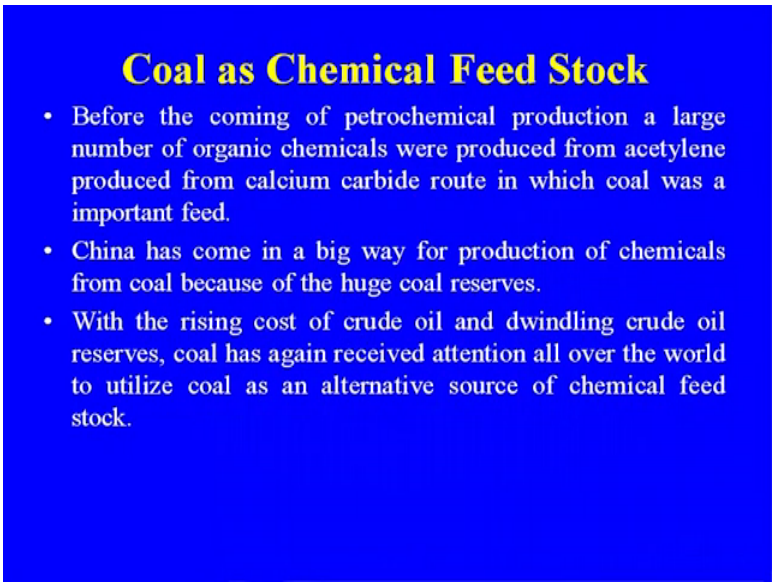

Before coming of the petro chemical production, a large number of the organic chemicals were produced from the acetylene, produced from the calcium carbide route, in which coal was a important feed stock. China is come in a big way for production of

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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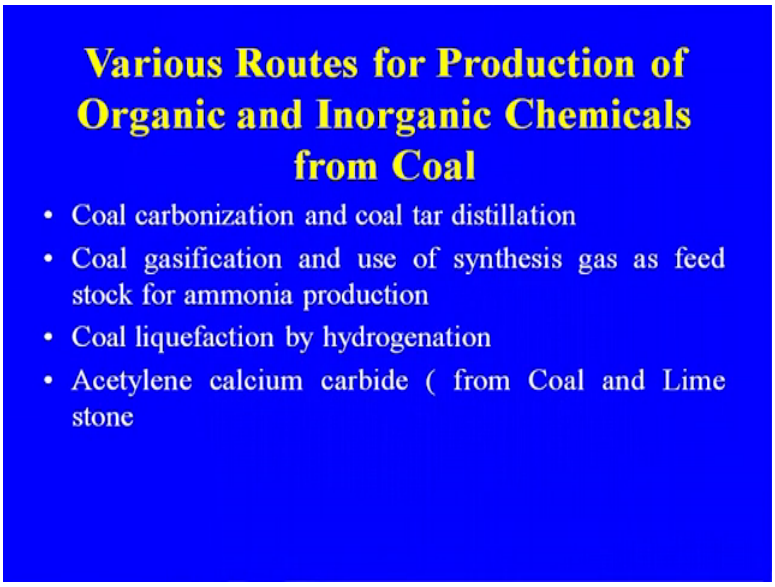

Various routes for the production of the organic and inorganic chemicals, coal carbonization and the coal tar distillation, coal gasification and use of synthesis gas as feed stock for ammonia production, coal liquefaction by hydrogenation, acetylene from the calcium carbide.

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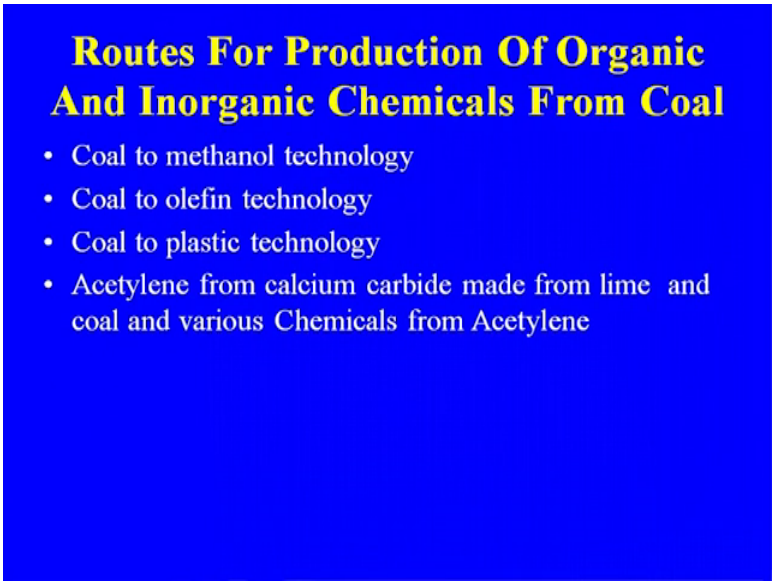

These are the some of the technology, which has come during the recent year and getting importance in utilization of the coal that is, the coal to methanol technology. Because, that is the in in intermediate, this is the also of course, the production of the synthesis gas and from the synthesis gas to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

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

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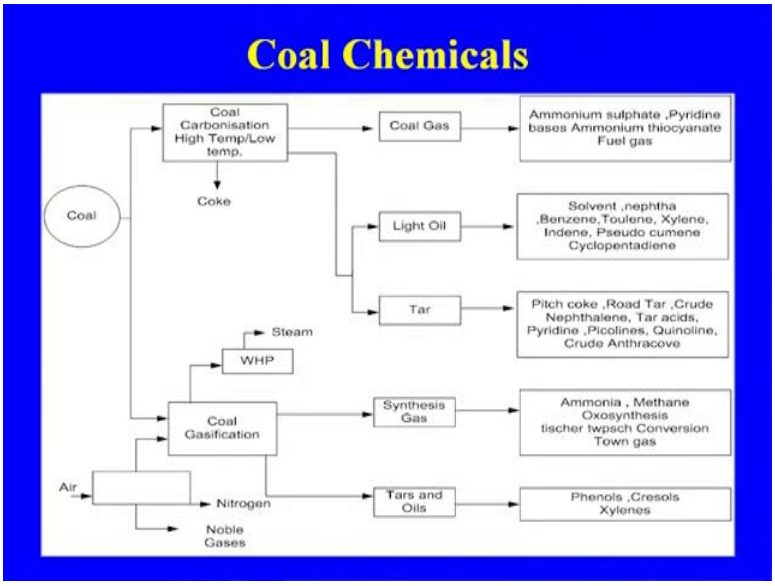

Coal, coal carbonization, high temperature, low temperature carbonization because two types of the carbonization were taking and we are getting the coke and the gases, and the coal tar that we are using for the production of the your various actually, the inorganic and organic compound. Ammonium sulphate 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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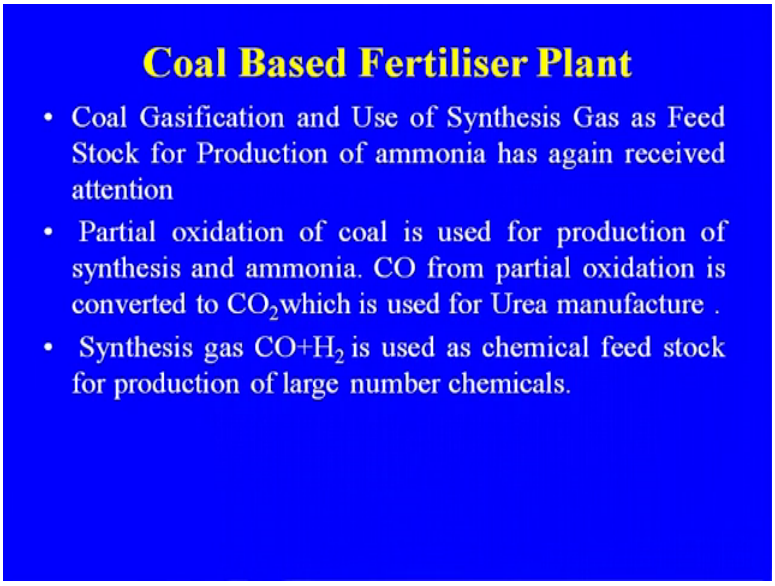

And the coal gasification and use of the synthesis gas, as feed stock for production of the ammonia has again received attention. Because. two units we were having earlier, when we stared the manufacture of the ammonia and the urea at the our Ramagundam and the Talci plant of the FCI, which was later 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 CO 2, 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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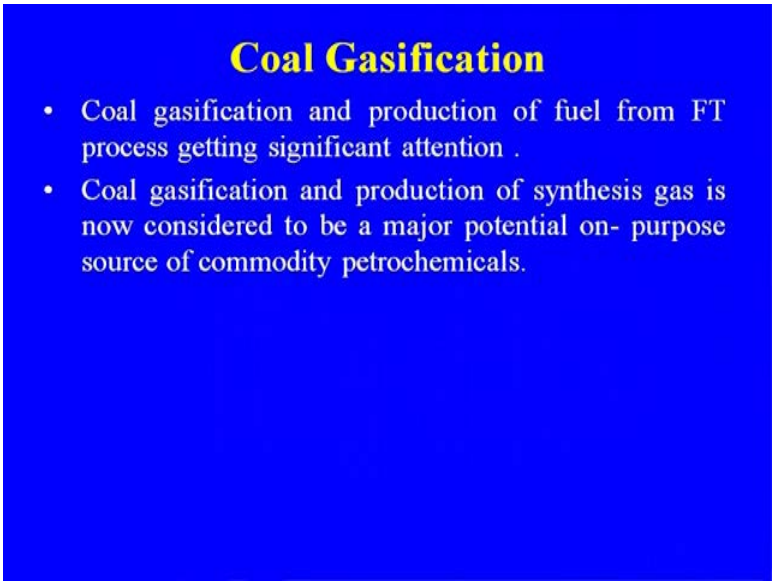

Coal gasification, production of the fuel from Fischer Tropsch synthesis getting significant attention during recent years. Coal gasification and production of synthesis gas is now, considered to be a major potential on purpose source of commodity. Petro chemicals, which are now being produced through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

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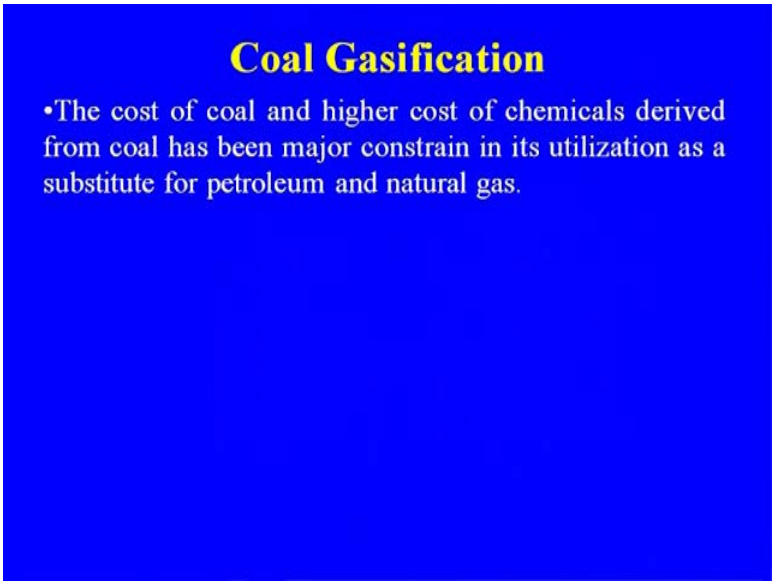

Coal gasification, the cost of the coal and higher cost of the chemicals derived from the coal has been major constrain in it is utilization, as a substitute of the petroleum and

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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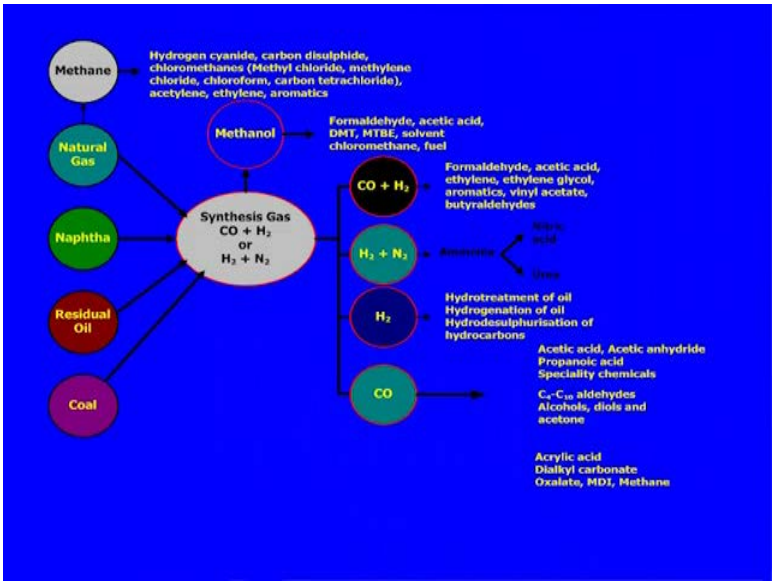

This is in brief about the actually the various products, which we are getting from the synthesis gas and so, the methane, natural gas and naphtha you have seen. But, one source from the coal, you see from the coal because this actually the various product from the synthesis gas that we will be discussing, 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 H 2 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 CO 2 after conversion of the CO 2 CO 2, and that CO 2 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 CO 2 is also produced. If you are not having the use of the CO 2 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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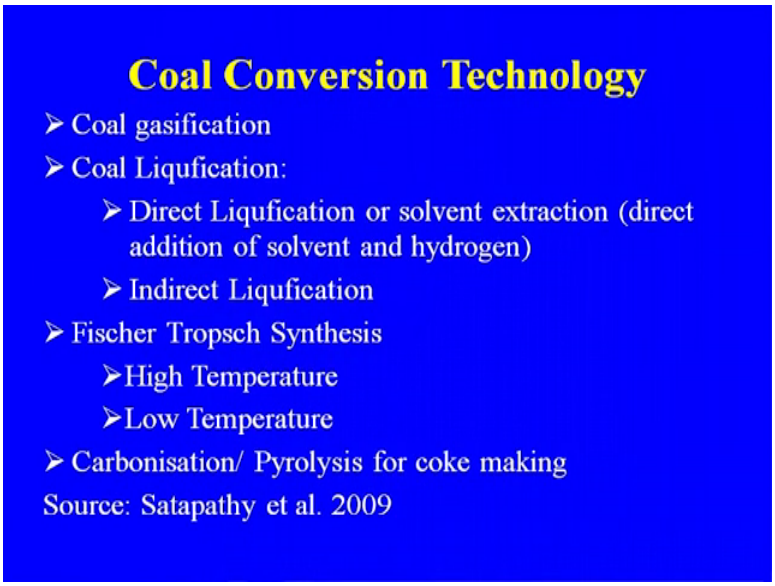

Coal conversion technology coal gasification, coal liqufication, that may be direct liqufication or the solvent extraction where the, we are adding the solvent and hydrogen, indirect liqufication. Fischer Tropsch synthesis, that may be again high temperature and low temperature, carbonisation pyrolysis 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 19 th 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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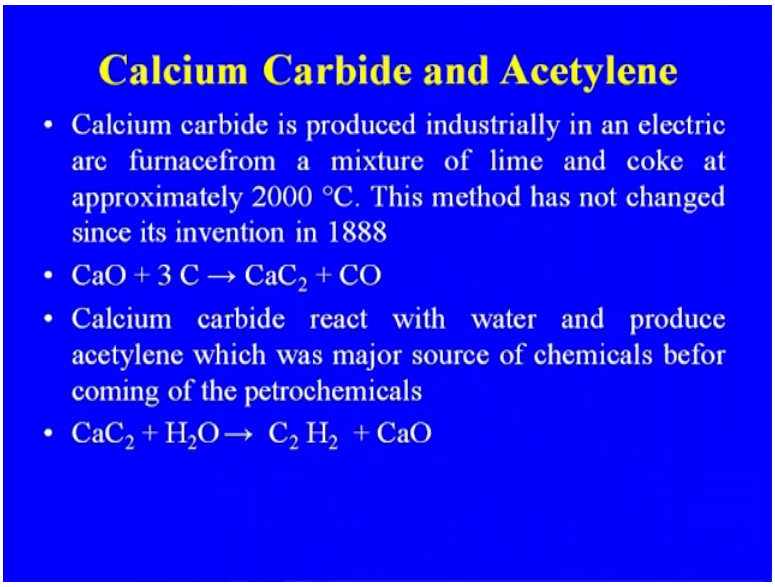

So, this is the process, how the calcium carbide and calcium carbine to acetylene production is there from after adding of the water, you are producing acetylene and the CO again we are regenerating.

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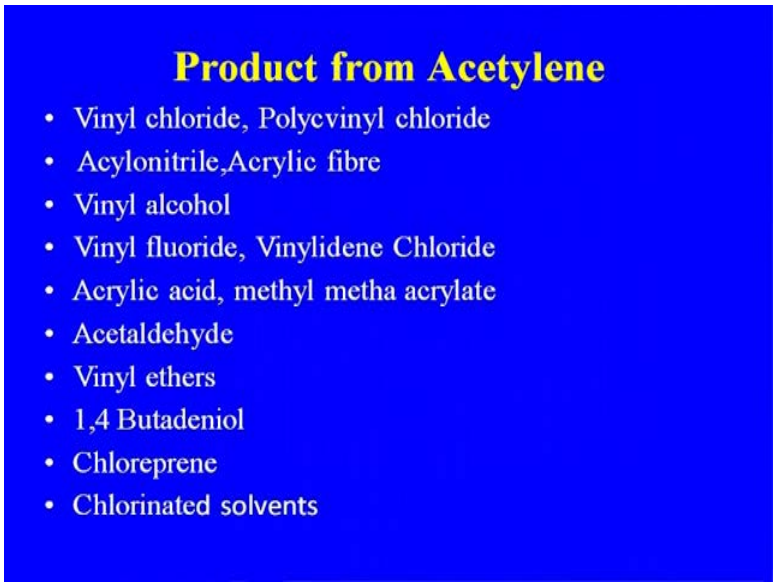

These are the some of the product we are getting from the acetylene, vinyl chloride polyvinyl chloride, acrylonitrile, acrylic fibre because earlier when the cracker plant was

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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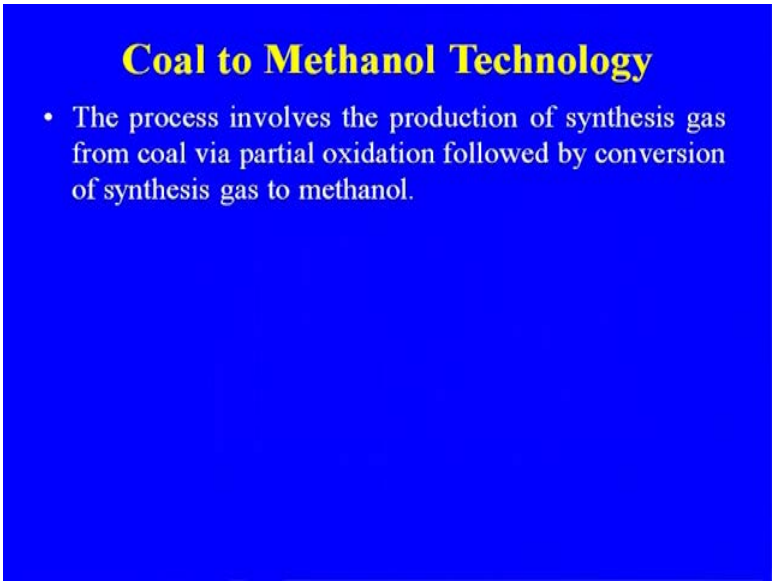

Coal to methanol technology, the process involves the production of synthesis gas from coal via partial oxidation followed by conversion of the synthesis gas to methanol, this is the technology that is been used for the production of the methanol. Again we will be discussing in detail about the production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

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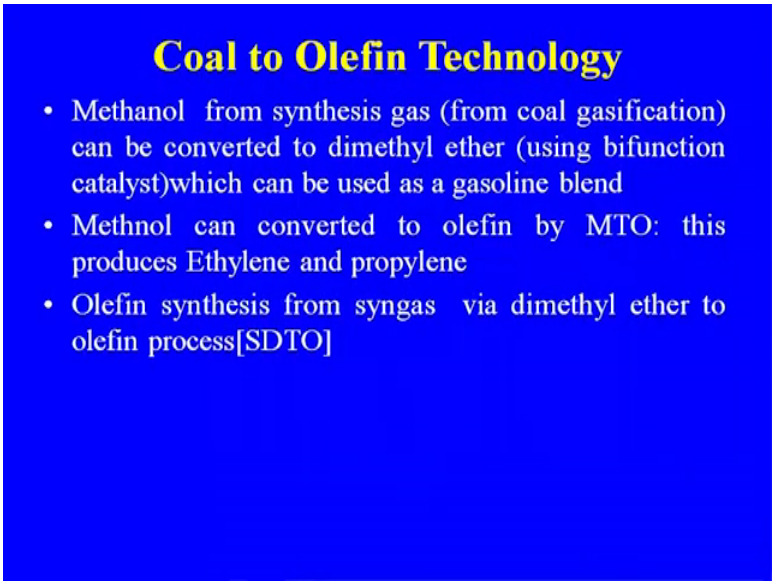

Coal to olefin technology, methanol from synthesis gas from coal gasification can be converted to dimethyl ether using bifunction catalyst, which can be used as a gasoline blend or methanol can be converted to olefin by MTO process. This this process produces ethylene and the propylene, olefin synthesis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

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Olefin produced from the coal route can be used for the manufacture of poly olefins and that is the poly olefin. 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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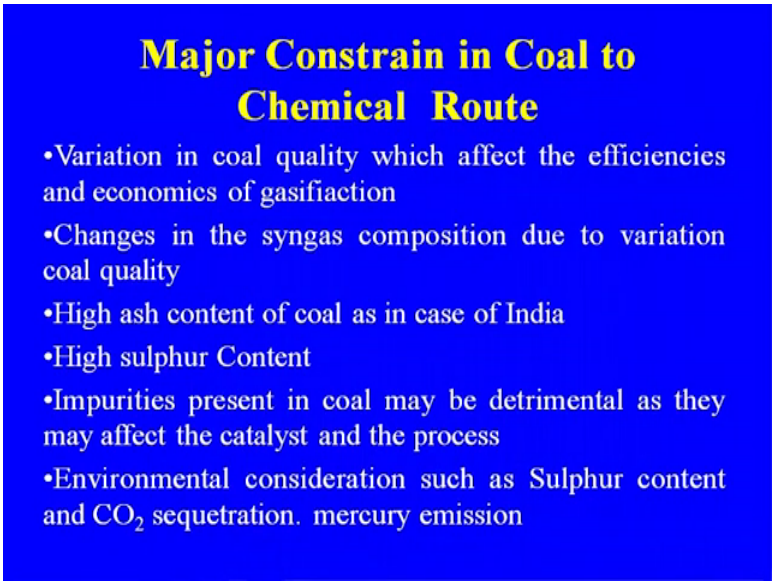

Because you see coal quality that is varying very widely from one place to another from one source to another source. And so quality even the, just you take the case of Assam coal, although it is having high carbon but very high sulphur content is there, some of the coal are having very high ash content. 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 CO 2 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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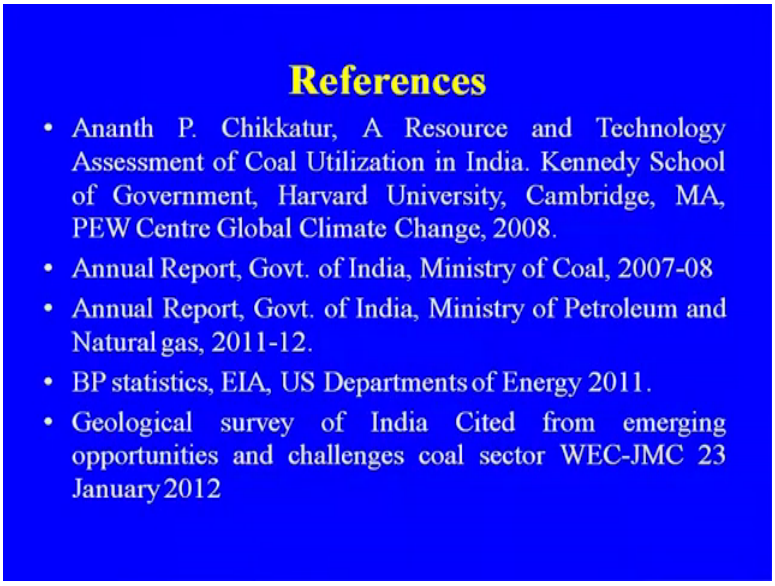

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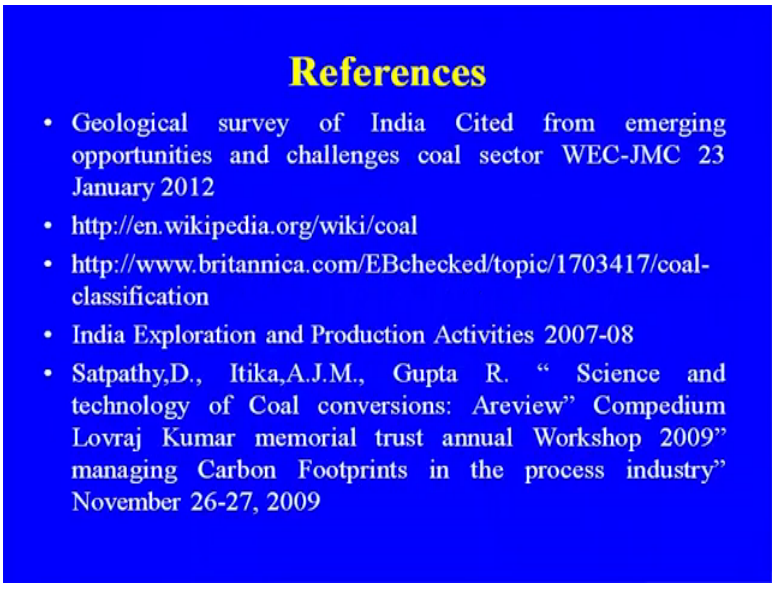

So, this was about the coal and the coal as the chemical feed stock in the lecture 2 of the module 2. We will be discussing about the coke oven plant because that was the starting of the production of the chemicals, which now we are seeing through the petro chemical route.