Natural Gas Engineering
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Module No # 01
Lecture No # 01
Introduction to Natural Gas - I

Hello everyone and welcome to the class of natural gas engineering this books class design for 20 hours lectures in eight weeks' time. Today's lecture is focused on introduction to natural gas I am doctor Pankaj Tiwari course instructor for this course.

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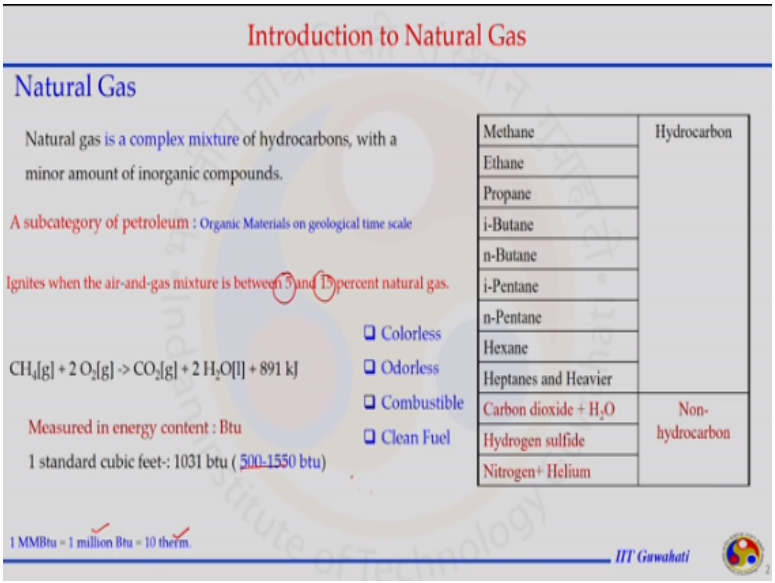

So let us go straight to understand what is natural gas? By the definition natural gas is a complex mixture of hydro carbon. Those hydro carbon ranges from C1 methane up to C7 C8 with some non-hydrocarbon gases like carbon dioxide, sulfur di oxide, water vapor trace amount of nitrogen and some rare gases like helium and others. So it is a mixture of hydro carbon and non-hydro carbon gases.

This hydrocarbon gases are combustible by nature and produce the energy when it is combusted. So it is natural gas comes under the sub category of petroleum. It follows the same theory as for the oil leak like the organic material underneath the surface gone through the geological

time scale heating under the pressure and got converted into gas as it is applied to oil. It ignites when the here and gas mixture is between 5 and 15.

So 5 is the lower explosive limit and 15 is the high explosive limit or higher explorer limit the combustion reaction goes like this. $CH_4 + 2O_2$ gives 1 moles of CO_2 2 moles of H_2O with some energy generation that is 891 kilojoule. In general the energy is measure in terms of BTU and 1 standard cubic feet natural gas gives us the BTU between 500 to 1550 that depends on the composition. For example here the reaction is one just for the methane because is the dominating compounds of the natural but when higher carbon number or hydrocarbon gases are present in natural they produce more energy.

Similar time if non hydro gas is those are non-combustive the do not content any energy or present in significant amount or significant person they reduce the energy of gas that is why the energy content of natural gas varies from 500 to 1550 BTU. So another unit which is commonly used for the natural gas is therm that therm = 1 million BTU, 1 million BTU 1 MM BTO.

The natural gas is colorless, odorless, combustible and clean fuel it is odorless so it does not smell to have the deduction capacity of this gas some are captions are like (())(03:35) added in the natural gas to deduct it is leakage or its presence.

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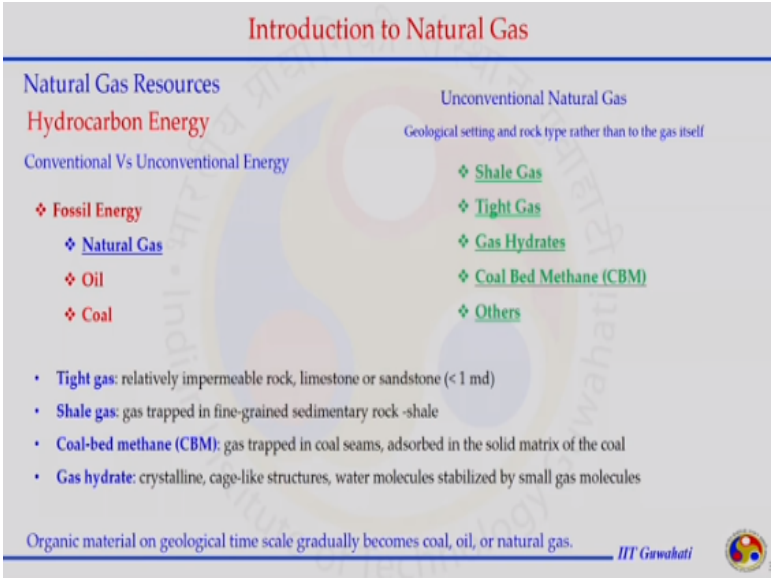

Natural gas comes under the hydro carbon energy sector under it can be classified as conventional and unconventional energies source. Under the conventional like fossil energy so for example natural gas, oil and coal becomes under the fossil energy and all are being produced under the conventional technology natural gas is a gaseous fuel, oil is the liquid fuel and coal is the solid fuel.

The important point is natural gas is present in natural gas reservoir in coal reservoir and as well as in the coal streams. So natural gas having the presence in all three fossil fuel energy sources under the conventional natural gas geological setting and rock type rather than to the gas itself define the unconventional forces this is not the composition of the natural gas are different or the altogether completely different.

When we talk about the unconventional natural gas it is geological setting is how natural gas is trapped in reservoir formation and in the coal streams and how long it was there under what geological formation is got trapped define a shell gas, tide gas, gas hydrates and coal bed methane and other sources those may be possible those can fall under the category of unconventional natural gas sources.

So tide gas it is relatively permeable rock like a lime stone or sandy stone with a very low permeability like less than 1 milli Darcy and gas is just trapped there similar in the shell gas. Gas is trapped in fine grand sedimentary rock like a shell structure and two extract the natural gas from these sources certain kind of fractured need to be created. We will discuss this unconventional energy sources in detail when we will be discussing unconventional energy almost at the end of this course.

Coal bed methane is also unconventional energy resource where the gas trapped in coal stream it means it is adds or in the solid matrix of the coal. Gas hydrate is another form of the unconventional resource of natural gas where the gas molecules are in the form of crystalline structure that is similar to the case like structure where the water molecule stabilize by small gas molecule is the one gas molecule like either a methane or very light hydro carbons are trapped by water molecules and that form is called gas hydrate.

It is (()) (06:26) there is a plenty of these unconventional natural resources are available across the globe the theory is similar gradually the organic material got converted into coal, oil and gas.

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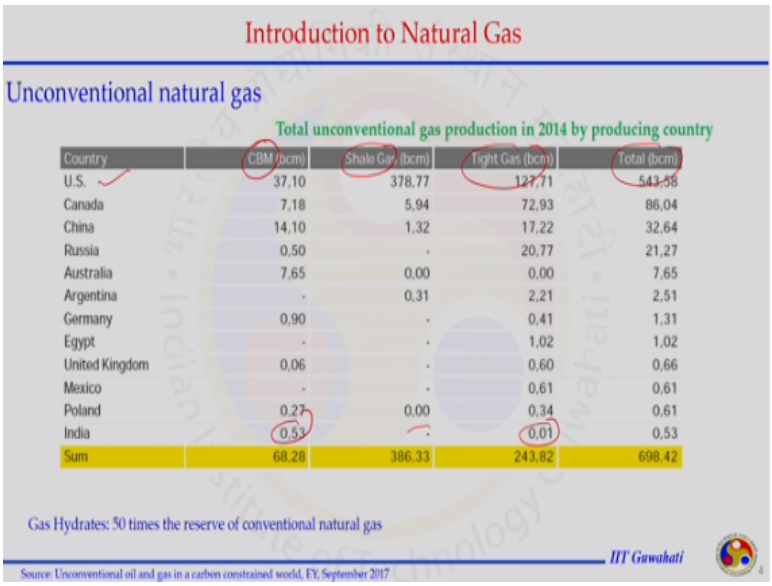

If we look unconventional natural gas resources across the globe there are several reports published every year like energy outlook, EIA and energy information administration from USA and several others they publish the data based on the data collected from different countries not only about the supply and demand all form of the energy what they are uses in different sectors like industry, domestic sector, residential sector, transportation sector and what are the new forms of the energy are being introduced.

So for examples when the unconventional natural gas explode they were also become the part of that study. This slides shows in different countries what are the reserve in the form of coal bed methane for the natural gas production in shell gas, tide gas and total are available. You can see here United States is having the most unconventional energy reserves in all the form either it is coal bed methane, shell gas and tide gas.

Similar this list does not include about the gas and gas hydrate and it is the gas hydrate reserve are 50 times the reserve of conventional natural gas. So huge amount of the unconventional natural gas is available that still either being explode or under the exploration process united

states had developed several technology like how to fracture effectively to get the gas out of shell gas similarly how to extract the methane or lighter gases from the coal bed methane.

In coal bed methane mostly it is light it is methane gas while cases shell gas and gas hydrate it is methane plus lighter fraction of hydro carbon like C2, C3, C4, C5 up to this list include for several countries India is also which is having the reserve for the coal, bed, methane. While other sectors like shell gas still under the exploration some report value for the tide gas is present.

There are several report as I mentioned and if you see if you compare the data published in different reports you will see there is a disparity between the data reported those data reported in a particular report depends on the data collected and the model applied. Especially the model applied to project the future energy demand if you see in a particular report there is a X amount of energy worldwide or in a particular countries required.

And how this energies achieved by different sector or different form of the energy may be different slightly with the others. But these reports are very good in terms of deciding or projecting the data in which direction the world energy demand and supply ratio is going to be and what are the sources those can meet this demand and supply relationship.

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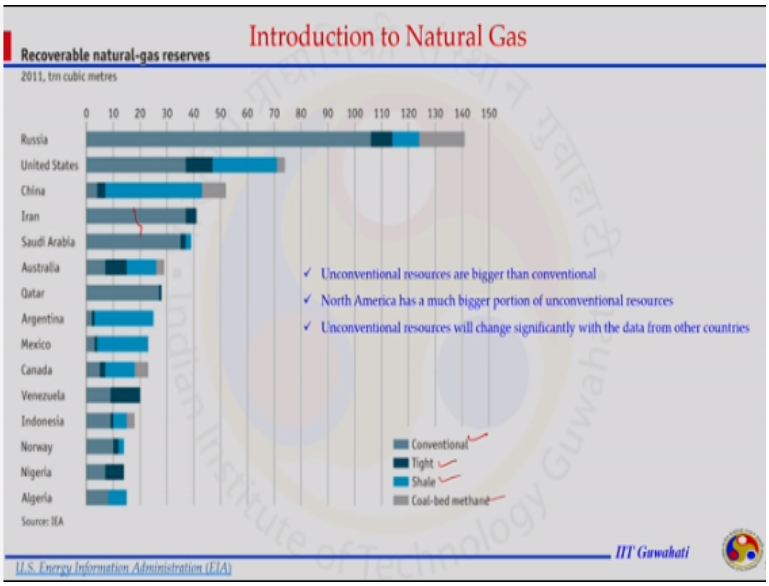

So in 2011 EIA published the data the resource different countries and their conventional tight gas, shell gas and coal bed methane reserves in the year of 2011. You can see Russia is dominating in terms of natural gas similarly after Russia it is middle-east Iran, Saudi Arabia they are having most of natural gas or conventional reservoir while in terms of unconventional it is United States which is dominating in all sectors.

So we can say altogether unconventional resources are bigger than the conventional resources north America has a bigger portion of unconventional resources in terms of the feature of the natural gas America is going to dominate in terms of the reserve they are having in the form of conventional energy of natural gas tide gas, shell gas, coal bed methane. Unconventional resource may change as I explain the data provided by particular country in a particular survey or study or the model applied when we talk about forecasting the data.

So the data may change depend on the sample data collected and processed to make certain assumption and decisions.

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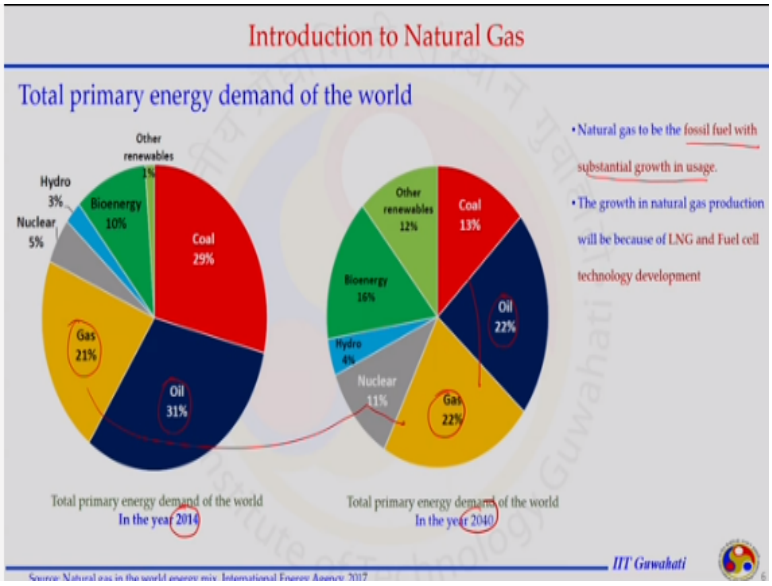

So here I can show you the total primary energy demand of the world the data taken the sources given below you can see several reports are published like this is from the international energy agency in 2017 they had published the data and where it compare like 2014 how the world energy is supplied by different source or form of energy like oil contributed 31% to the total energy need of the world while gas was at 21%.

Similar coal was at 29% and other like renewables, bio energy, hydro and nuclear energy where also added in this study. When this study was projected for future like in 2014 we can see the gas is 22% from 21 to 22% oil is going to down side like 22% but this is again the energy need will be more in 2040 compare to 2014 to meet that higher demand or energy demand in 2040 this study projects like the gas will be contributing more compare to other fossil like coal and oil.

So the coal and oil will be partially or significantly be replaced by the natural gas so natural gas to be the fossil fuel with substantial growth in uses. In the future the growth in the natural gas production will be because of technology being developed to utilize natural gas effectively like LNG fuel cell technology where the fuel cell need hydrogen and where that hydrogen can be produced by steam reforming of methane to get the hydrogen for the fuel cells.

This fuel cell technology being developed and to get the hydrogen methane or the natural gas may get a significant market there and other technology like the uses of natural gas in a different form like GTL may significantly be advance in the technology thus the contribution of natural gas will also be more.

Another data set that can be projected here like this is for the world energy if we look in a particular country in the United State in 2000 itself the natural gas was contributing about 22% of the total country need and it was projected like where 2010 this will meet around 25% and that is happening. Natural gas not only from the conventional reservoir but because of the exploration and utilization of the unconventional energy resources more than 25% of more than 25% energy requirement of United State is being fulfilled by the use of natural gas.

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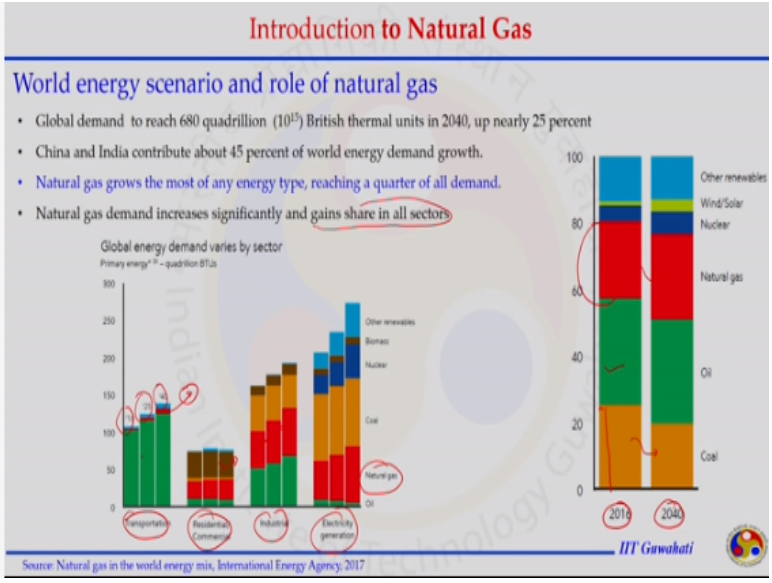

So world energy scenario and role of natural gas global demand is supposed to reach 680 quadrillion BTU into 2014 as per the assumption this is 25% increment will be 25% of that energy will be shared by natural gas it is expected. China and India contribute about 45% of world energy demand growth because of the industrialization is happening because of the population these developing country like India and China they need more energy and that energy can be fulfilled with the help of natural gas or the conventional unconventional natural gas resources.

Natural gas grows the any energy type and reaching a quarter of all demands so we see here in this chart 2016 data which is projected to 2014 we will see coal contributed around 25% this is oil contribution and natural gas also significantly share the total energy supply. It is projected like in 2014 the share of coal will get down while the natural gas will increase. The total need will be classified in four major segment like transportation, residential, industry, electricity generation we can see 3 years 2016 projected here 2025 and 2040 we see in transportation it still mostly dominated by oil.

Oil in residential as in the western country or especially in the USA natural gas is used a heating media or heating fuel for the houses and the building. So natural gas significantly share the uses as a fuel for the residential and commercial sector in industry also natural gas is having its own sector it is own market and it is supposed to be increase as we go further in terms of time. Similar for the electricity generation natural gas is going to dominate compared to the

coal because of it is property like it is clean in terms of emission it is religious to environment compare to coal.

Natural gas demand increases significantly and gain shares in all sectors we can see in all sector natural gas is going to get it is share even in the transportation if you see compare to 2016 in 2014 natural gas contribution is higher this is because of the it is believe like the technology will be developed where the natural gas can be converted into liquid fuel or may be the engine may be modified to accept the natural gas as the fuel.

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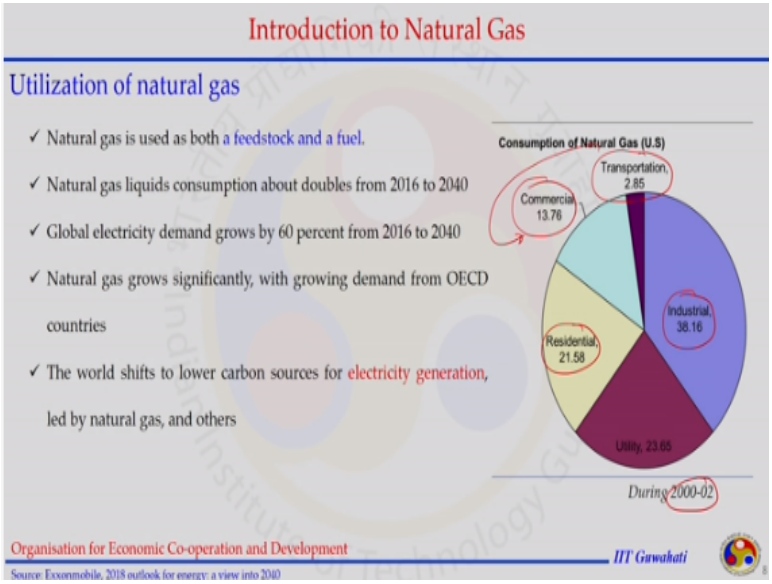

Utilization of natural gas it can be used both feedstock for petro chemical and fertilizer industries as well as fuel for several sectors especially electricity generation. Natural gas liquid consumption like this is NGL it is about to be double by 2040 it is projected data again in one of the report published in 2018. Global electricity demand grows by 60% and the need to this electricity demand natural gas is being considered as a prominent source.

So the world is shifting to lower carbon source for electricity generation led by natural gas and that is others may include solar energy thermal energy and other sector. If we look on typically chart that is the energy demand or the consumption of energy natural energy in the united states the natural gas is being utilize in commercial sector like 13%, transportation 2.85% industry 38.16 % and residential 21.58%.

So this charts shows in 2000 to 2002 the transportation sector was using very less amount of the natural gas but if the technology can be developed as I said either in the form of fuel cell those can be use in the vehicles or in terms of converting gas to liquid the transportation sector will be consuming significant amount of natural gas to meet its need.

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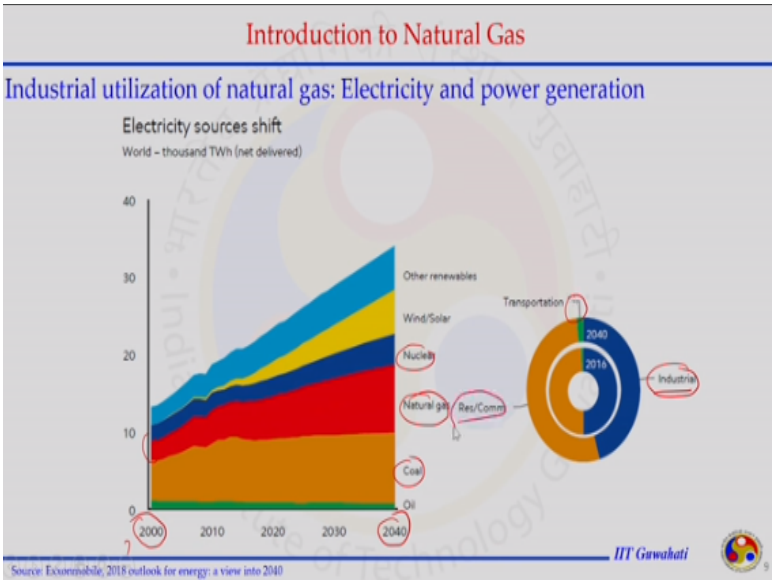

In terms of industrial utilization as I said for electricity generation the data if plotted from 2000 to 2014 this report is published into 2018 again. So some are the history data some are the projected data and you can see the coal is almost becomes stagnant in terms of the contribution to meet the electricity generation as a fuel natural gas is increasing its contribution as a fuel to generate the electricity significantly you can say from 2000 from a small area it is going to a bigger area like here nuclear and other will also be contributing significantly because the energy demand will also be increased by 2040.

If we look in the pie chart the electricity generated from all these sources will be utilized mostly industrial, transportation small sector and residential sector will be consuming more.

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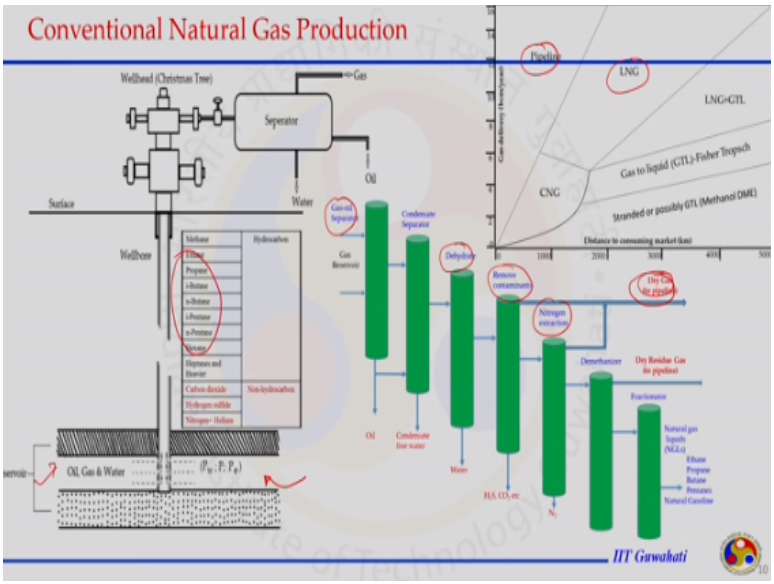

So with this back ground let us come to the class of this natural gas engineering which is designed especially for the conventional natural gas production system. Unconventional component was added in this class that will be discuss in more detail about the tide gas, shell gas, coal bed methane, gas hydride and some other form of the natural gas produced from other sources like the pyrolysis of some carbonate material altogether this course is supposed to discuss primarily on the conventional natural gas production.

So this is the production system if you see here the reservoir from where the gas is being produced through the wellbore reaching to surface facilities the separator is there that is separating multi faces of present on small amount of gas is small amount of oil, water and some sand particles for that before the natural gas goes to consumer it is supposed to process with several unit to refine the natural and further it needs to go to transportation sector where it will go to end user. Those end user these are may be customer individual customer may be industry or some other organization.

So we see in the second week we will be discussing about properties of the natural gas because during this entire process natural gas composition changes. If we are having one particular well the composition will be different composition in the sense is methane, ethane, propane, butane they are percent relatively will change.

Yes methane will be dominating in all the forms and some inorganic gases will also be present in some unwanted they are just waste they are not having any energy value not only energy value they also create a problem during the transportation or utilization. For example water vapor S2S the corrosive in the nature S2S is like very fatal gas we will discuss all these removal processes. Here as you can see the natural gas that is being produced from this porous reservoir domain because of the pressure difference it is having certain composition in term of hydro carbon and non-hydro carbon gases.

When this gas is travelling all the way to surface it is reaching to separator where the oil, gas and water will be separated. After that it will go to separator after separator it will go to dehydration where the water will be removed and then it will go to removing the contamination is especially S2S CO2 and then nitrogen extension ultimately whatever the composition of the reservoir is producing they may change or they get change after each process.

And because of that the properties of natural gas changes because of properties of natural gas as it is not a ideal gas the property gets changes and we need to value at them at a particular condition the natural gas is available. For example under the reservoir pressure condition the properties will be different when it comes to surface the properties will be different and when it is passing through each unit because of the composition changes and because of the temperature and pressure condition changes the properties will be different.

So you see here whatever the composition of natural gas at different stages in most of the cases the natural gases that goes to consumer is mostly pure methane with a small trace amount of the other hydro carbon and non-hydro carbon gaseous. Natural gas which is also containing some higher hydro carbon compounds those are having more value there more energy density material for example over domestic LPG cylinder is butane and propane that is having more energy than the methane.

So the more energy compound can be extracted and most and the unwanted or impurities like CO2 S2S needs to be extracted before it is being sent to pipeline to restore and users the gas will take different terminology different names those will be discussed in the next slide.

After processing the transportation sector will come and transportation we are having the relationship how much amount of the gas should be transported and at what distances should be transported will decide in which form this should be transported.

For example if it is a long distance and a long and significant quantity we may have to choose either the pipeline or LNG. LNG is liquefied natural gas depend on the (()) (25:14) is going to phase and the distance it is going to cover one of the option may be chosen we will discuss transportation or other converting usual gas into other forms like GTL gas to liquid and LNG liquefied natural gas we will discuss in detail when we will go through this course.

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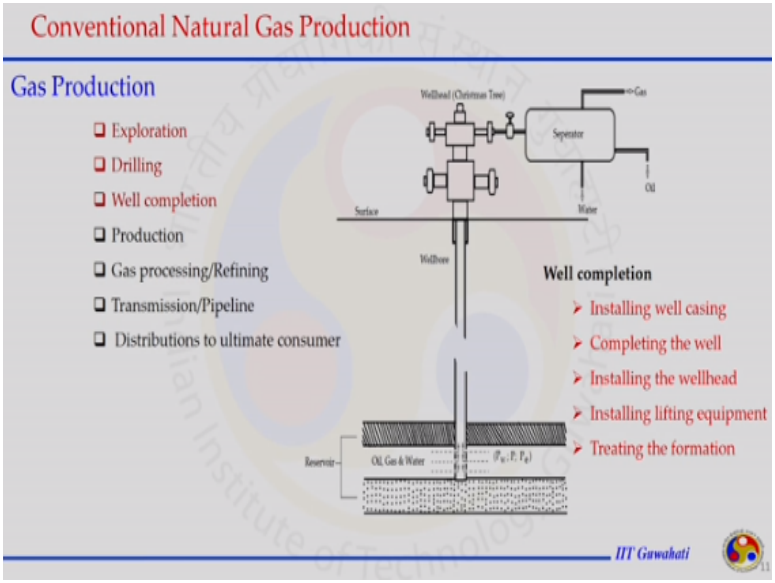

What we can discuss in today's class is about how natural gas is produced and what terminology is used to understand the natural gas production system. So conventional natural production if we see here this is again the same diagram where the natural gas is produced from the reservoir and this process goes through several steps conventional natural gas production is not a one main job.

It is a team that involves from starting of exploration to drilling to well completion then production, gas processing refining, transportation, distribution to ultimate consumer in include all sort of the people those are expert in for example dealing with the legal resource making the decision reservoir engineer those understand the reservoir and geologist those

understand the geology of the formation refining gas, drilling engineers all sort of the team they discuss and they decide conventional natural gas production fate.

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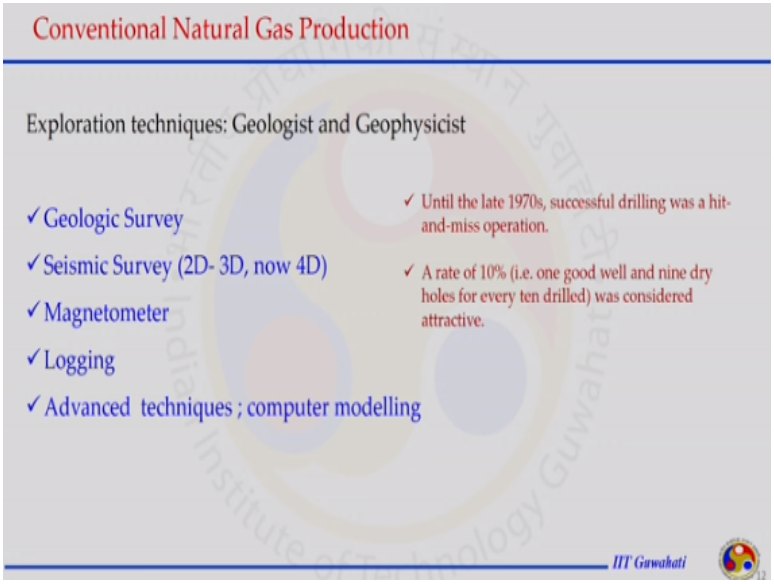

So if we begin from a exploration technique this is a job done by the geologist and Geophysicist. The geological survey are done by the geologist they collect several data set and geophysicist understand the rock formation of put those data to together to understand the formation. And based on the exploration technique it is decide at a particular location the well should be drilled or not drilled these are the similar technique as use for the oil exploration similar or used for the gas exploration.

Like the geological survey are done to understand the geological of a particular reason where there is a possibility of finding natural gas or not. With the advance of the technique like Seismic survey the chances of getting success is high as example it until the late 1970's successful drilling was the hate and miss operation as if you are going to find out a location where there is possibility of finding fossil fuels like for examples oil or gas before drilling it was hate and miss operation and it is success ratio was 1 ratio 10.

If you are going to hate going to 10 wells may be the ratio it is just 1 place where you are getting significant potential reservoir gas or oil then 9 are just going as a dry well but with the advance of the technology like this Seismic survey in a 2D, 3D and now 4D form the data

are collected and they are able to give a good estimation of where to drill and how to drill at a particular location that can be done with the help of seismic survey data.

Other data form like magnitude meter where the magnetic properties of reservoir rock is used to collect the data and logging data where the density log or some other rock log data are recorded during the drilling time or during the processing time to understand the geological formation and where is the possibility of drill and the possibility of getting the gas or available there.

Advance techniques like computer modeling are being developed and they are having a more chances of predicting the natural gas resource at a precise location. Now the success rate has been improved from 14% in 1970 to 49% in 2000 I do not know the recent data but it is getting advance with the advancement in the technology those are associate how to explore the data and where to drill or not to drill decision making process.

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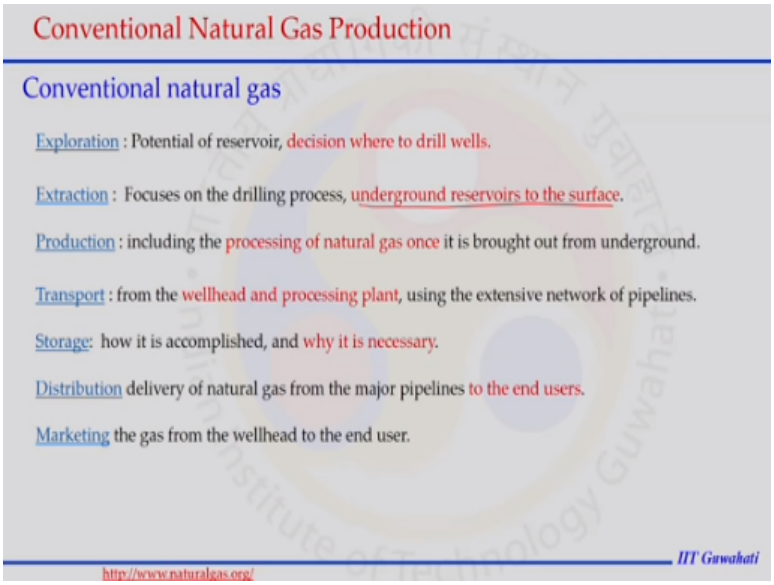

So I summarizes some of these steps like exploration that decide the potential of reservoir and that is put a question to take a decision where to drill the wells. Extraction once the location has been identified it is decided we are going to drill at a particular location.

So the extraction of steps comes and that says how to drill or how to perform the drilling process underground reservoir to surface means from the underground reservoir or the fluid is

available how to bring it to surface is a job of drilling engineer or it is a part of drilling process. Several complication process comes during the process which type of drill should be used and what type of the muds should be used several steps come in that part that we are not going to discuss in detail.

Then after extraction it comes the production that says natural gas that is brought to surface from the underground how to process the natural gas by using different techniques. Once refinement as done gas is ready to be used it needs to be transported from the place of production to end user that should be accomplished with some transportation media and that could be either by laying down the pipe line or by LNG or by converting some other form.

The storage how it is accomplish and why it is necessary should also be consider during the conversion naturally gas production. As I said during the summer time the natural gas is being produced it has less market time compared to winter time because during the winter time the more gas or natural gas is required to heat the houses and building to maintain the comfortable temperature.

Distribution delivery of natural gas from the major pipeline to end user thus also need to be considered during the business of natural gas production to consumer marketing the gas from the well head to the end user. So other than this steps also several steps are involved in those I skip these are the highlighted step decides those describe how the natural gas business start from first place exploration to marketing when the end user are using it and a natural gas is being used either as feedstock or as a fuel.

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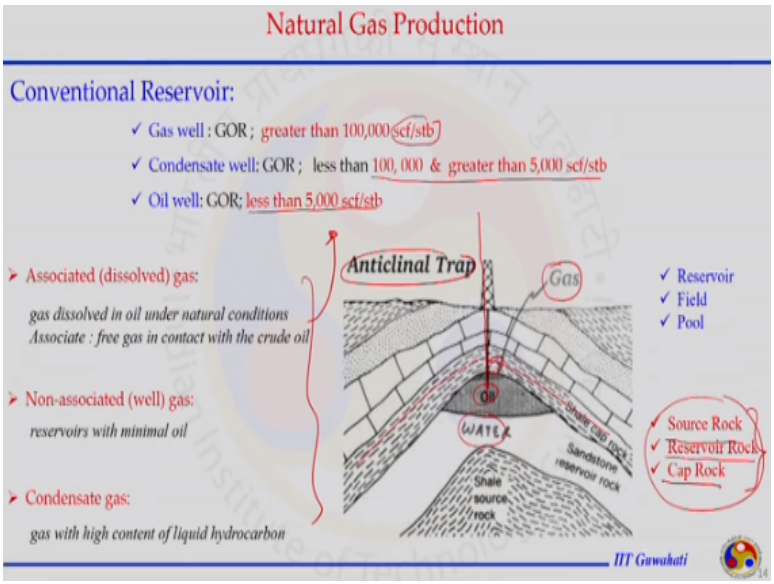

So let us come to conventional reservoir and this slide it shows how to know once location have identified these drilling has been completed the production is started how to know this type of reservoir it is. It is a gas reservoir it is a oil reservoir or it is condensate well reservoir means the condensate well is also producing the liquid along with the gas. So to do that there is term called GOR gas to oil ratio it means when the fuel is produced from a particular well we can separate it at the separator and quantify how much oil and how much gas is produced from this particular well.

And if you calculate gas to oil ratio in the unit of standard cubic state to standard tank barrel if the ratio is greater than 1 leg is it considered there is a gas well it might be containing some more small amount of the oil but it is mostly the gas well. Oil well if the ratio is less than 5000 scf per stb means it is mostly the oil and just gas is associated or dissolved in the oil. Condensate well where the ratio is between 1 lakh and 5000 the well is called condensate well.

So once the production is started to identify which type of the well it is because that decide what type of surface facilities should be installed if it is a gas well the surface facilities install will be different then the oil similar not only the facilities to refine the gas but to collect the samples. So the GOR value that decides which type of the well it is depend on several factor how the fluid or produce underneath how they accumulated in a particular reservoir location where they are being produced.

So this is can be happened mean several ways one of the things that I highlighted here is a antic lineal trap since antic lineal trap the gas is the reservoir is in a tomb shape where the fluids are got trapped. So to have the fluid or the petroleum result in the reservoir there should be three types of the rocks available like this source rock where this geological time style thermal under pressurize condition is happening and the organic material is getting converted to coal, gas and oil that source rock should be available.

In our case this source rock should be able produce the gas and there should be reservoir rock or permeable rock through which the sand through which is the gas being travelled to a location where it can get accumulated in a significant quantity and there should also be in a gap rock which is impermeable rock and not allowing this fluid to come out to surface but it is on. So to have the reservoir or petroleum reservoir these three types of rocks must be present in a particular domain then only we can have a significant or potential reserves of the petroleum fluid.

Like for gas it is a gas reservoir this and anticlinal trap that says that is in this shape were the gases on the top then oil and water got accumulated oil on the top because of the less density compared to oil and water and sometimes this gas it is called the this production from this anticlinal or the arrangement in this form is called as a gas cap dry reservoir.

So when the well drilled here it depends on the location from where we are producing either will the other produced first or the gas will product first or the water will produce first and later one it will be a mixture of oil, gas and water.

Considering this we can say in any reservoir so there is a definition of reservoir field and pool reservoir is a place where this organic material getting converted to petroleum sustenance and those petroleum substance got accumulated in a significant potential quantity to be produced field is like several reservoir with a similar structure is present in the same reason while the pools with the different structures the reservoir are present is called the pool.

Another classification is for any particular reservoir associate gas reservoir or non-associate gas reservoir. So if the reservoir is producing a gas with oil and the gas is dissolve in that oil is

called the associate gas reservoir. Associate gas reservoir is also comes under the category where the free gas is in contact with the crude oil so when we are producing the oil the gas is also being produced while it is not even dissolving in it these called the associate gas reservoir means the gas is being produced in the association of oil.

Non association gas means it is just gas that is being produced or with the very minimal amount of liquid or the oil is been produced. Third category as condensate gas with high content of high liquid carbon so with these definition if we club this represent the similar what is GOR in a numerical term if less than 5000 it is oil if greater than 1 lakh it is gas well. If it is in between this is a condensate well.

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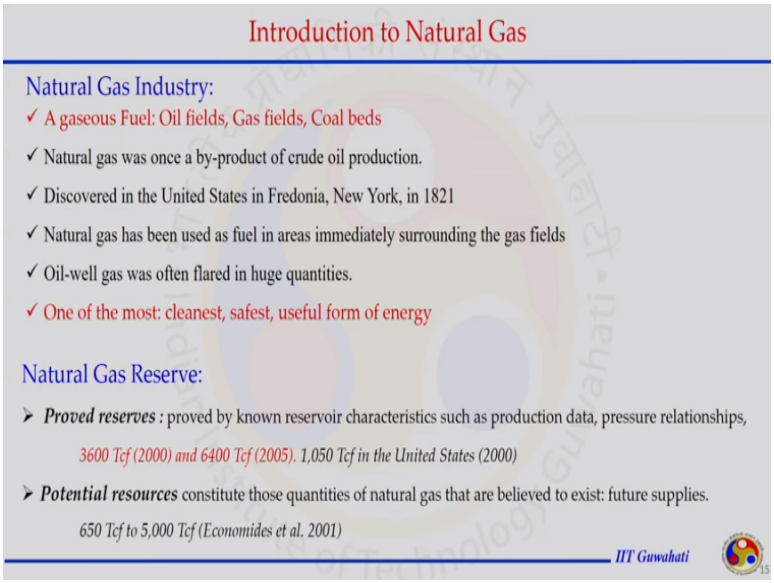

Natural gas industry if we look towards the natural gas industry sector and the history of the natural gas we can say a gaseous fuel natural gas is a gaseous fuel it produces with oil field, it produces in gas field, it produces in coal bed also. Initially natural gas was just a byproduct of crude oil production so we go to history there are story about natural gas. For example people were not aware about the natural gas it was being released to the atmosphere without knowing what gas it is.

In ancient type the natural gas when it is catching fire by it is on it is just getting fired people were not aware about why this fire is there. It was found discovered in United States in Fredonia, New york in 1821 and since then the uses of the natural gas and the discoveries

are having significant disparity sometimes it is used even it is discovered it is used for the local purpose only for example in the oil production system where the natural system is also being produced natural gas is used just for local users like energy record for the oil field or just in the nearby reason just to light the lamp and other part otherwise most of the cases it is just (())(39:41) to the atmosphere.

Natural gas has been used as a fuel in area in immediately surrounding the gas field because there was no way to store it there was no way to transport it from one place to other place it was having no value and the only of option left either use it in local area or in the surrounding or just either flared it and let it go to atmosphere natural gas is also greenhouse classified now we cannot let it go to atmosphere even if you want because contributes to greenhouse gas effect.

Oil well gas was often flared in huge quantity so far it is being like significant amount of quantity of natural gas is already flared and this practice is still in some of the countries where the natural gas is not having any local market when natural gas is not having any mean of transporting from one place to other place to use it, it is being flared to the atmosphere. One of the most, cleanest, safest useful form of energy is natural gas despite having all these things where of the lack of infrastructure in the older type or in the past it could not be used very effectively.

Now if you see the trend from the place of no use of natural gas now we are exploring unconventional energy resources that shows the potential or the energy need which can be met with the help of natural gas. So gas that was having no value, no recognition now we are developing the technology to use it very effectively.

When it comes to reserves of the natural gas they are classified into two parts like fluid reserves and two potential reserves fluid reserves are either drilled and we know what is potential of that particular reservoir it is proven that this much natural gas will be produced if we collect all the data we can say worldwide this much the proved reserve or in a particular country this is the proved reserve.

Potential reserve are the estimated data those are based on the experience based on several assumption or based on believe, based on scientific evidence it will believe like this much amount of natural gas is still to be explored and that is potential reserves are available those can be used to made the future energy demand.

If you go by the data 2000 it was reported 3600 trillion cubic feet natural gas reserves is available that is still the crude reserve not the potential reserve but in 2005 the data has been reported to 6400 trillion cubic feet and this depends on the data collected not only data collected but if the new field of natural gas or explored new reserves are found and that is reflect in this quantity. In united itself in 2010, 2000 the data says 1050 trillion cubic feet was the proved reserve.

Potential reserve constitute that those quantity of natural gas that are lead to adjust that is where the data are not accurate because the countries those are exploring the gas or producing the data they are having the estimate of the reserve of gas that can be available but certain reason of world when there is no exploration there is no plan to estimate the natural gas or not accounted under the potential resources head and the value various from 650 trillion cubic feet to 5000 trillion cubic feet even this data is reported in 2001 the data may have got better with the advance technology those are getting developed.

So conventional natural gas production would be or going to understand how natural gas is produce from here to surface how it is controlled with the help of choke and then it is going to separator and several new unit. You see there are several terms are written like tri gas tri residue gas and NGL and some other gases those are the fraction of the natural gas those have been selected separately to send it to sell them out separately to get the more value.

In next few lectures after completing the properties of the natural gas we will be focus on the production from natural reservoir and processing.

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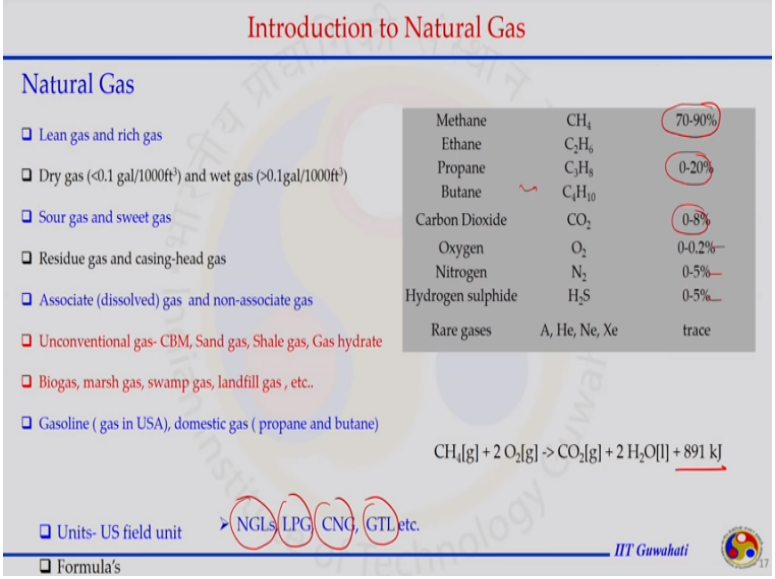

During this there are several definitions or terminology will appear we can discuss them one by one like for example lean gas and rich gas. Lean gas is mostly the methane gas which is purified, refined, valuable compound where extracted to sell them separately impurities were separated out before it is being sent to consumer while the rich gas is a gas which is having more carbon number hydro carbon like C2, C3, C4 dry gas.

When there is small amount of oil is present gas is mostly the dry gas which is having only the gas is compound present in it is called the dry gas, wet gas when they condensate compound or the condensate are present in the gas the wet gas the gas is called the wet gas in terms of quantity 0.1 gallons per 1000 feet kilo if the data say 0.1 galloon liquid is per 1000 feet cube present if the value is less than this number it is a dry gas if it is higher than this number it is wet gas.

Other terminologies sour gas and the sweet gas if the natural gas is containing S2S CO2 miss the gases those are sour in nature they need to be separated out while removing this gases and after that process. The process is called sweeting process and after sweeting process the gas is called the sweet gas. Residue gas when all the compound has been extracted the residue gas that is going to send to transportation line to send it to consumer is called the residue gas. And the casing hide gas the gas which is being produced from a reservoir and reaching at the well head is called the casing head gas the composition of the residue gas will completely different than the casing at gas.

Case and head gas will be higher carbon number hydro carbon number as well as non-hydro carbon gases in it. Associate gas and non-associate gas we already discussed in detail the associate gas can be in the form of dissolve gas or just the free gas are just being produced in the oil non associate gas which is having very minimal amount of oil present mostly it is the gas unconventional gases we discussed the CBM, sand gas, shale gas, gas hydrate more detailed discussion will be done later on when we will be discussing unconventional energy resources and they are contribution to natural gas uses.

Other terminology bio gas, marsh gas, swamp gas, landfill gas so this terminology will appear old time marsh gas swamp gas, landfill gas were(()) (47:51) natural gas also. Gasoline it is different in the natural gas in United States or in other countries gasoline is also called the gas when you going to any gas station it does not mean you are going to get the natural gas it is gasoline which is being sold at that station. Domestic gas that is not actually the natural gas it is the combination of propane and butane.

In United State field unit system mostly business of the natural gas system in the US field unit system. So when we are dealing with the natural gas we should be more careful about the unit system we are choosing. During the course you will see several formulas are there and those formulas are big because of the complexity involved in the process especially are in because of the properties of fluid means the natural gas or changing with temperature and pressure.

The form could be natural gas could be in the form NGL could be LPG, CNG, GTL we will understand all these term one by one during this course altogether what we can say natural gas is having the composition dominated by methane 70 o 90% it is methane, ethane, propane, butane contribute altogether between 0 to 20% and some higher hydro carbon can also present in the trace amount carbon di oxide CO_2 is 0 to 8% oxygen is also in the small amount.

A small amount we are having the nitrogen that goes up to 5% hydrogen sulphide up to 5% and rate gases like organ, helium, neon in fact natural gas is the primary source of getting the rare gases. The reaction says it is combustible by nature and it produces the energy so that is

why natural gas and it is utilization to produce the energy becomes important not only because not only the natural gas content the energy that is why it should be considered as future energy source.

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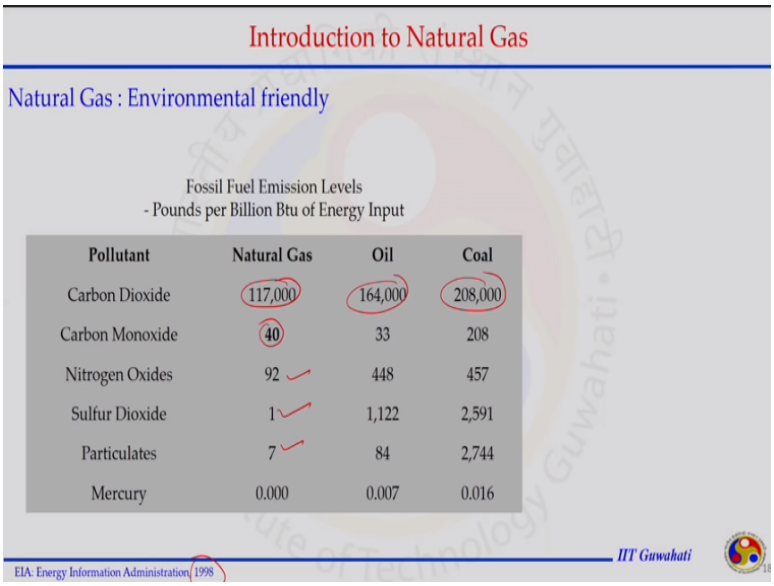

But under the carbon constant wall when we talk about fossil fuel utilization and compare natural gas with coal and oil emission religious by natural gas combustion to atmosphere or less compared to oil and coal. This chart shows about fossil fuel emission level per pound emission level pounds per billion BTU of energy input. So to get the similar amount of energy like natural gas, oil and coal we are burning them combusting them the carbon dioxide released from natural gas is less than oil and coal.

Carbon mono oxide is slightly higher reported but it is also can be converted to some other form like (()) (51:09) gas and then later on to like other form. Nitrogen oxide is less sulfur dioxide is less particulates are less mercury is not present altogether it is reported in 1998 the natural gas can be considered very environmental friendly fuel it religious very less polluted to environment and compared to other fossil fuel like oil and coal should always be given the preference.

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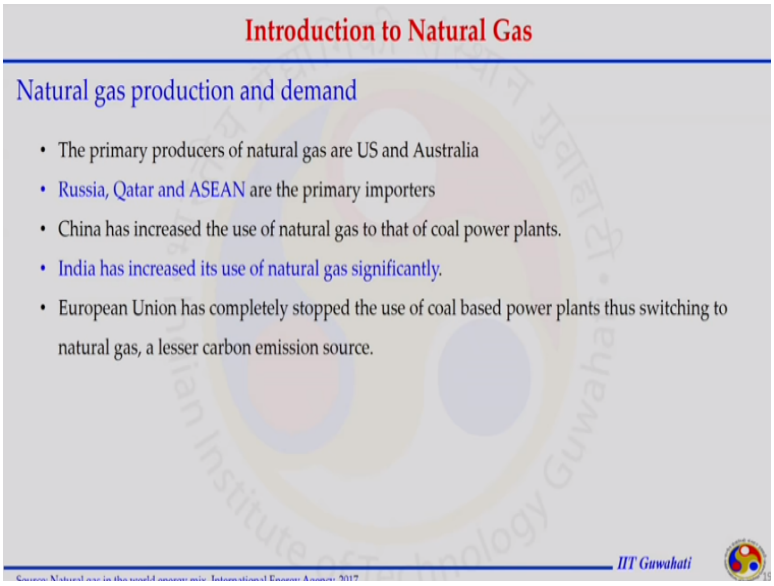

So natural gas production in demand if we see this scenario the primary produces of natural gas or USA an Australia, Russia, Qatar or ASEAN are the primary importers. China as increased the use of natural gas to that of coal power plants so the primary use of the natural gas in China replacing the coal and using natural gas as a source of energy. India as increased it is use of natural gas significantly.

So India also need natural gas now European union has completely stopped using of coal based power plant the switching to natural gas and lesser carbon emission source altogether what it says due to the nature of natural gas, Natural gas is being considered in several countries as a source of energy especially for electricity generation due to less emission but it depends on availability of natural gas in that region.

How natural gas can be transported or imported and exported from one point to other point for example United States it imports natural gas as well export the natural gas. So in part of the country it is importing another part it is exporting because of the nature of the natural gas transportation business in which form it can be transported either it can be transported by pipeline could be in the form of LNG or some other form.

It becomes important yes natural gas can be used as a very effective environmental friendly source of energy but is it available or not similar when natural gas is available in what form it can be used or the pipeline or install their which has been flair to the atmosphere. So

import and export business will going to govern how effectively natural gas can be utilized to produce the energy.

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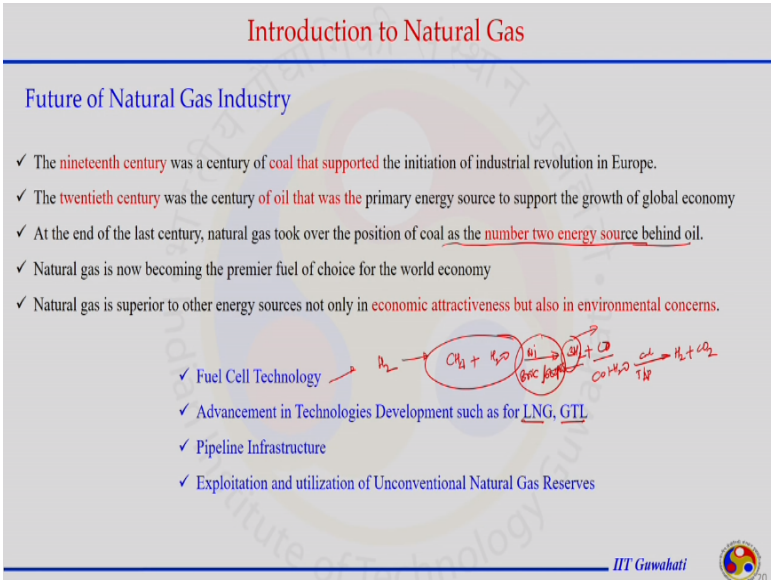

When we talk about the future of natural gas industry nineteenth century was considered to the century of coal that supported to initiation of industrial revolution in Europe and in rest of the world. The twentieth century was the century of oil suppose it was coal that was used very that was used for energy generation later on it came to oil and oil was used in twentieth century especially for the support of global economy because of the transportation fuel at the end the last century natural gas took over the position of coal as the number two energy source behind oil.

So now coal is being replaced by natural gas and especially in the electricity generation sector natural gas is now becoming the premier field for choice for the world economy because of it is nature of environmental friendly and due to imposing of carbon di oxide, carbon emission releases the world is moving towards low carbon emission fuels and natural gas is getting a good place in that segment.

Natural gas is superior to other energy source not only economy attractiveness but also in the environmental concerns. If we see the future of the natural gas industry we see it depends on the several factor it depends on from where the natural gas is being produced how it is getting produced it is conventional natural gas production or unconventional natural gas

production are you importing the natural gas or you are exporting natural gas or you having local market for the natural gas or you are supposed to install the facilities to utilize the natural gas and how the advancement are happening in terms of the technology development to utilize natural gas.

For example fuel cell technology, in fuel cell technology we need hydrogen and that hydrogen can be produced from methane + H2O this process is called steam reforming and if it is done for example under (()) (56:07) at a temperature range of 800 degree Celsius and 600 PSI it produces S2 + CO the conditions can be modified for developing the ahh technology developing the catalyst suitable catalyst reducing the temperature and pressure requirement.

But because of this steam reforming of methane we can produce H2 that can be used for fuel cell and carbon mono oxide. That carbon monoxide can go through the reaction CO + H2O at a some catalyst and some temperature and pressure condition mostly it happens at mostly at atmospheric pressure condition to form S2 + CO2. So altogether by having methane as a source of fuel are source material or field stock we can perform this steam reforming and can produce the hydrogen for fuel cell technology.

For this technology you can get advance significant amount of natural gas will be record similar for the GTL like (()) (57:18) if a better advancement can be done to use effectively gas to convert into liquid more natural gas will be required and when it is getting more need the business can be set of effectively and the price can be reduce significantly. Advancement in technology development for LNG and GTL that I just discussed pipeline infrastructure again that I said how it is being transported that is also the matter of it is business development it is easiest.

From the today's lecture what I would like to convey there are significant possibilities of using natural gas as a premier fuel source because of environmental concern because of its availability and not only it is under the expectation United States and several other countries are meeting their energy need with a significant quantity of natural gas. So it is already stepped is natural gas is a much better cleaner fuel in the other fossil energy sources like the oil and coal.

With this I would like to end my today lecture in tomorrow lecture we may continue the similar discussion or we will also cover about the phase behavior of natural gas. As it is said natural gas is a mixture of hydro carbon and non-hydro carbon. So when we are dealing with the natural gas under the PVT or thermo dynamics behavior like pressure, volume and temperature condition.

When the conditions are changing how natural gas will behave will be understood with the help of the phase behavior studies like it is a liquid phase or it is in the gas phase or it is sharing some part of liquid phase and some part of gas phase depend on the temperature and pressure conditions with this I would like to thank you for listening the video and we will meet in the next lecture thank you very much.