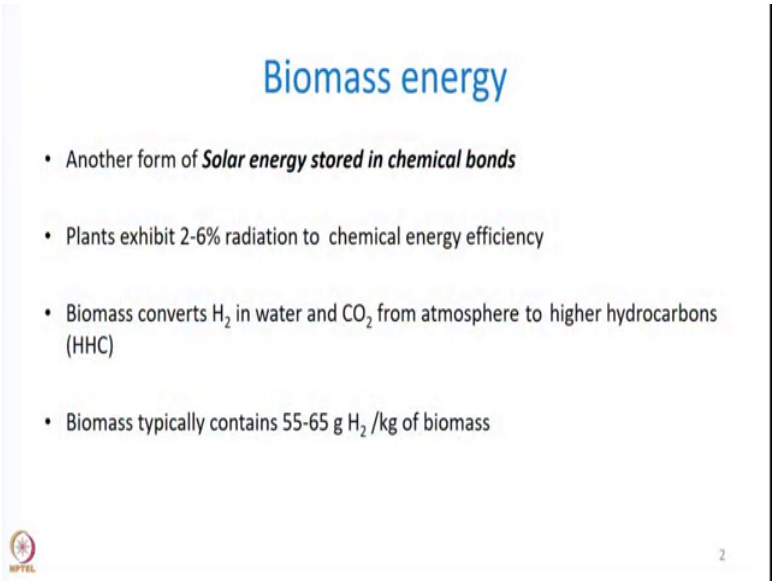
Hydrogen Energy: Production, Storage, Transportation and Safety

Prof. Sandeep Kumar
Department of Energy Science and Engineering
Indian Institute of Technology, Bombay

Lecture - 15
Hydrogen Production from Biomass Part - 1

Hello students, Welcome to the course and myself Professor Sandeep Kumar from Department of Energy Science Engineering, IIT Bombay. So, I will be taking this particular module where we discuss about the hydrogen production and hydrogen energy from biomass and coal. So, these particular two areas which are also prominent potential sort of source where we can generate hydrogen through it, and we will discuss about the overall chemistry and overall process of the hydrogen generation using biomass and coal as a feedstock.

(Refer Slide Time: 01:15)



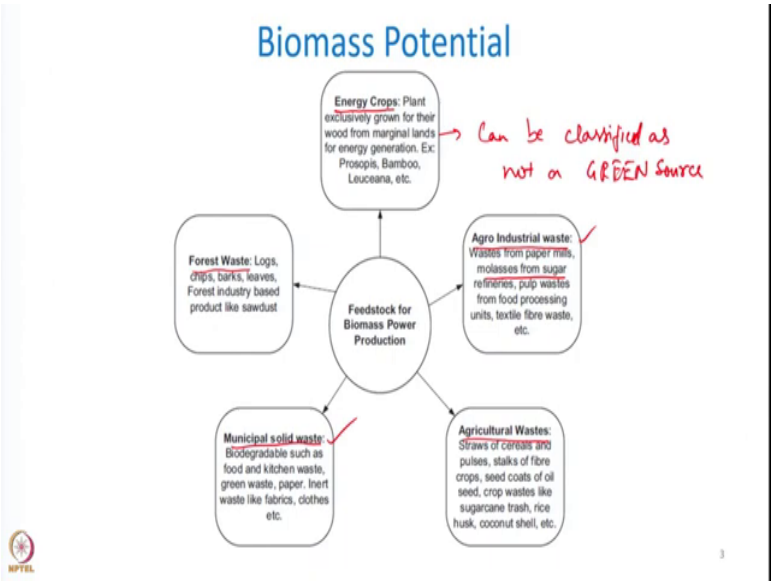
So, welcome to the course and we will start with the introduction part like when we say about biomass energy; biomass is a another form of solar energy stored in the chemical bonds. So, and it is not about only the biomass energy when we go and discuss about the coal and all of you also know that the coal has also has an origin from the biomass. So, lot of things are common when we discuss about the biomass and the coal, and also when we discuss about the process there will be lot of commonalities and that is why I want to start with biomass because coal is a refined form of your biomass.

So, when we say about biomass it is also an indirect form of your solar energy. So, which is stored in your chemical bonds. So, plants typically exhibit 2 to 6 percent radiation to chemical energy efficiency and biomass typically converts hydrogen in the water and takes CO_2 from the atmosphere and makes the higher hydrocarbons and that is a typical photosynthesis process that all of us know about. So, biomass typically contains 55 to 65 grams of hydrogen per kg of dry biomass.

So, this 55 to 65 gram is the hydrogen that is contained in the chemical bonds with carbon and the oxygen and other organic molecules. This does not include the moisture and the wet part of the biomass that is in the bounded H_2O, but not in the chemical bond. So, these are found in the as a water like we know 90 percent of our body weight is water and lot of biomass that you find in the nature it has lot of water.

But when we dry it and when we look only into the chemical sort of formula wise how much is the hydrogen contained in that dry biomass, that is around 55 to 65 grams of hydrogen and this is typically what we are trying to recover and we will see that how we can even get more than that.

(Refer Slide Time: 03:20)



So, now when we come to the biomass potential: So, biomass potential typically when we look into there are two different aspects: one is the energy cultivation or what we called as the energy crops like as you might be knowing that Brazil is actually sort of growing sugarcane to harness bioethanol. In the US they are growing sweet corn to harness bio ethanol.

So, bio ethanol from sugarcane in Brazil or from sweet corn in US, they are actually examples of energy crops or the energy cultivation. So, this is one particular aspect, other aspect is when we look into the waste. So, when we look into the waste we have this forest waste, which is the age old practice. These are the logs, chips, barks, leaves.

It means if you look into the rural sort of lifestyle they also use these forest waste or the tree waste that falls they do not cut the trees, but they collect this waste and this is what forms the their cooking fuel for the majority of the rural households, this is the sort of fuel for the cooking. Not only in India, but throughout the world this is the still the major cooking fuel comes from this forest waste.

So, when we look into other waste these are municipal solid waste, your agriculture waste, and your agro industrial waste. So, when we look into the agro industrial waste then it is the waste from the paper mills, molasses from sugar, refineries. I mean you have biscuit, ketchup, chips industry and also when they are using any biomass they are not using 100 percent of that thing to convert it into their desired product, but there is a lot of waste generated into it.

So, just for example, molasses from sugar; so, sugar cane juice is converted into sugar, but there is a lot of by-product and that is molasses, and that molasses is predominantly used for your bio-ethanol production. So, these are some of the things where your waste from an industry which is using the agro product or similar things and those waste or by-products can also be used for some sort of useful purpose or some energy recovery or some chemical recovery and this particular module of the course we will discuss about how we can recover hydrogen from this waste biomass.

So, another is your agriculture waste. So, agriculture waste is typically lot of like these are something which all of us know when we have wheat, when we have paddy, when we have corn the only the fruit part or the seed part is actually desired product or the useful product and rest of the stock of the plant goes as a waste.

In the past couple of years the burning of these paddy straw or this agriculture waste in the fields has been a big concern especially in the northern part of the India where it is one of the major reason for the smog or the particulate matter pollutant in the northern part of the India during the winter season.

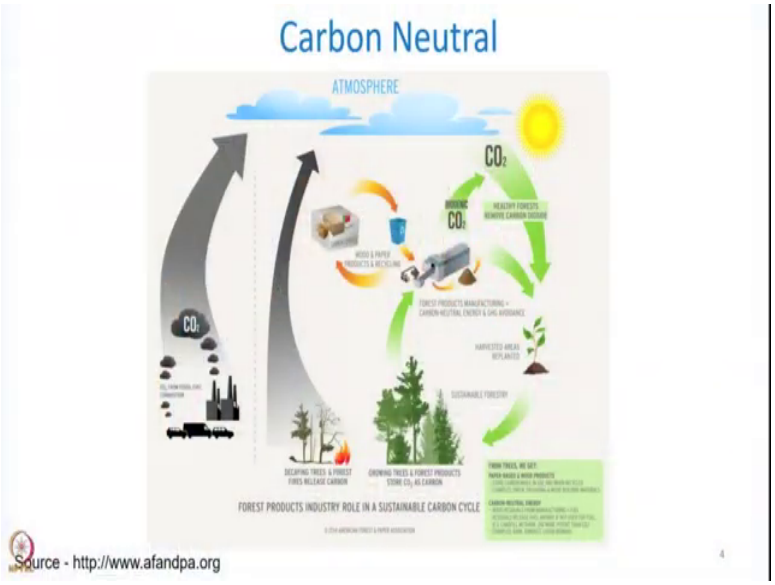
But this also has a very great potential where we can harness hydrogen from it and another one is your municipal solid waste. So, municipal solid waste is actually all the carbonaceous product, carbonaceous product which has similar sort of you say chemical properties where we have a carbon as a source which we can use to harness hydrogen.

So, when we discuss about the overall chemistry we will be able to appreciate. Then that whatever the waste that is carbonaceous in nature can be used to sort of harvest your hydrogen from it that does not matter whether hydrogen is there in or not there in the feedstock or the waste. So, it includes this municipal solid waste includes your biodegradable waste mean paper and inert waste like fabrics cloths and all and even the plastics.

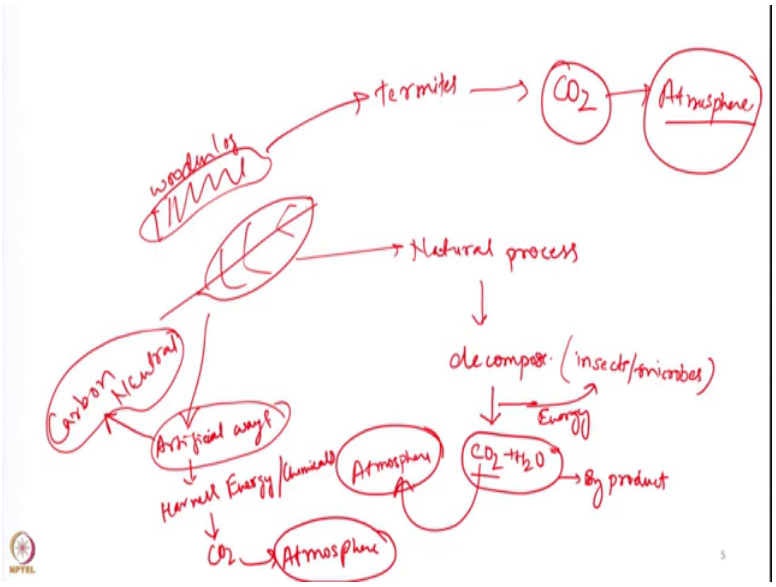
Plastics which are carbonaceous in nature can also be used, but yeah it is not a biomass, but yes it has a potential to get the hydrogen from it. So, another aspect when we discuss about bio mass as a source for hydrogen or energy or as a renewable energy source then there is a lot of debate.

And we need to understand when we call biomass as a source of energy or as an any useful chemical like hydrogen whether it is carbon neutral or it will be classified as carbon emitter. So, there are actually different aspect there is a lot of debate, but we need to understand the basic when we say biomass waste when we use it is carbon neutral then what does it actually mean.

(Refer Slide Time: 08:59)



(Refer Slide Time: 09:07)



So, let us say for example, you have a dry piece of log or you have a dry piece of a leaf just say this is your dead leaf that has fallen in your backyard or in your garden what will happen to this leaf. So, this leaf, through natural process what will happen? It will get decompose, some insects or some microbes will work on it and they will recover energy because they are eating these waste or the dry leaf for getting the energy.

And, but it will also release $CO_2 + H_2O$ as a by-product. So, what we see is this CO_2 it gets back into the atmosphere and if this is your wooden log or dried wooden log and it is fed by termites. So, termites will eat your wooden log then what will happen? they will also release your CO_2 into the atmosphere. So, when we say that our energy harnessing process when we say artificial ways then harnessed energy or chemicals and your CO_2 gets released to atmosphere.

So, the basic crust of this philosophy is when we say it is something is carbon neutral is does not matter we take whatever the ways through multiple pathway your CO_2 will get emitted. One thing is when we burn directly or cut the trees during the deforestation and all those things doing the CO_2 emission. Then yes, we are into the CO_2 emission.

When we say energy plantation, so, like we discussed in the previous slide the energy crops it can be classified as not a green source. We may have cut down the trees, a jungle to make the pathway for the growing some sort of energy plant and same thing has been debated like

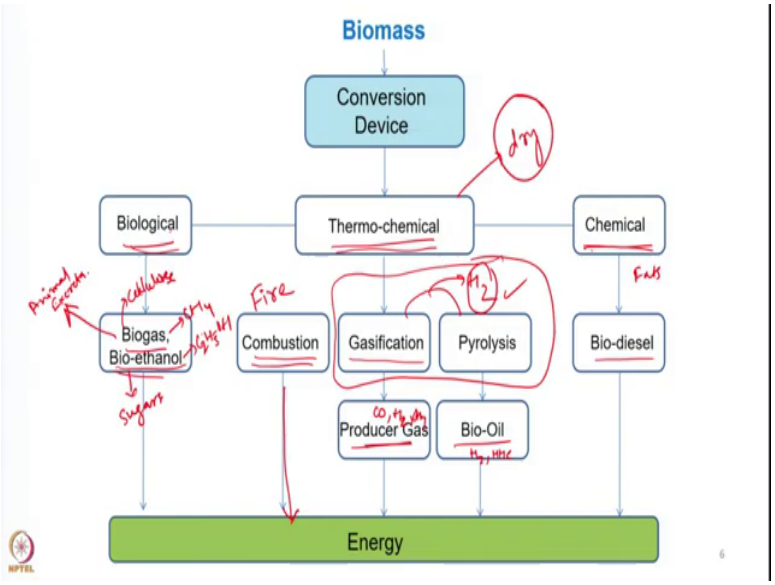
when we say in Brazil there is a debate like when we say that there yes, there is a lot of potential in harvesting biomass energy.

So, but while growing the sugar canes in Brazil they are also absorbing the CO_2 in the same way as jungles. But there is a lot of concern that when we destroy a jungle it is a complete ecosystem, deforestation and planting a selective trees or a crop does not replace the overall similar carbon potential or carbon, what you say the potential to absorb the CO_2 by a forest ecosystem is much higher compared to a selective crop sort of cultivation.

Whether it is a sugarcane or a sweet corn or any other sort of biomass especially if we are looking into energy plantation. So, then we can say definitely it may not be a carbon neutral system. But when we look into any sort of waste whenever we have products recycling anything which comes out of a factory agro waste or something as a waste then definitely this artificial waste becomes your carbon neutral. So, this is a philosophy about the carbon neutral and in this particular module of the course we will be discussing about harnessing or extracting hydrogen from the biomass.

But always keep in your mind that yes, this source of the biomass should be green source should be coming from waste or if it is from the energy plantation, how sustainable it is should be the question. So, with that philosophy now we move to the different ways of harnessing energy from the biomass.

(Refer Slide Time: 14:48)



So, this particular slide typically I keep whenever I take any lecture on biomass or bio energy one of the basic reason is that I just want to convey that in our society majority of the people they associate bio-energy with this biogas generation. So, all of us in our school days we have studied about the biogas, biomethanation and we associated that part as a bio energy source, but that is not the only thing we need to look into their multiple pathways of harvesting the biomass as a source of energy.

And if we classify it into broader verticals then we have this biological, thermochemical and the chemical. So, biological also biogas is not the newest technology that we as a human civilization we know the oldest one is the bioethanol and the combustion process. So, bioethanol we all know it is a 1000 years ago it is a thousands of years ago human civilization has mastered the way how to have a controlled biomethanation process.

Though it was not used for energy, but as a beverage, but alcohol is an example of the very good pathway of converting your waste it may be waste or typically when we look into the beverages and all definitely it is not the waste that is being used. But as a crop which is being harnessed and converted to alcohol, but when we look into the commercial practices getting sort of renewed nowadays.

Especially in India we have a policy the government policy we have the sugar mills cannot throw your by-product molasses of the sugar mills in the open, it has to be used and molasses is a very good source or good feedstock for your microbes who generate bio ethanol. So, the molasses is being diverted for bioethanol production and throughout India minimum 5 percent of that bioethanol is coming in the petrol as a mix. So, minimum 5 percent ethanol mix is there in the Indian all the petrol pumps.

So, if you are running your vehicle some part of that petrol that you see is actually bio ethanol and that part of bio ethanol is actually coming from your biomass waste through this biological pathway of bioethanol generation. And second major process is your thermochemical and here also combustion.

Combustion basically nothing but this is your fire we burn the dry wood and we get heat and light and getting the controlled fire for heating and lighting purpose that is actually the oldest and the biggest achievement of the human civilization or you can say invention or the innovation that human civilization has got was the having the control fire for the light and the heat.

So, this has been for thousands of years we have mastered this combustion and bio ethanol process, but what we are looking into hydrogen they are coming from these two pathway of gasification. And pyrolysis your combustion directly gives you energy gasification and pyrolysis gives you intermediate fuel just like your biological process is giving you methane and giving you alcohol C_2H_5OH.

So, these are intermediate you can use it as source of energy and here producer gas which will be having carbon monoxide, hydrogen and methane and bio oil also will be mixture of hydrogen and many higher hydrocarbon. So, there will be lot of things we will discuss in detail about this gasification and pyrolysis process which gives us this hydrogen which we can harness.

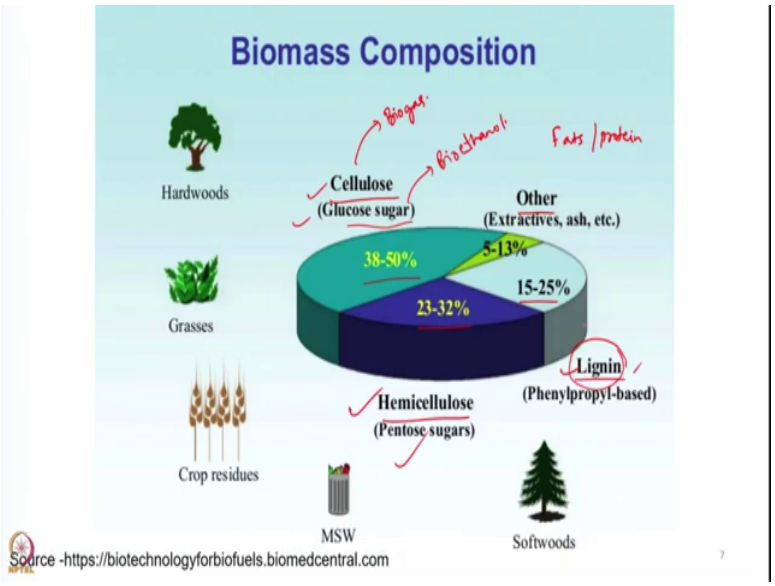
Another vertical is your chemical process and the prominent popular pathway that many of you must be knowing is the biodiesel. So, biodiesel harnessing from the high fatty acids content of the waste oil or some seeds like jatropha seed which can be grown in the arid section and all they are converted to biodiesel using a chemical pathway. So, they do not use the biological microbes and all to convert, but a standard chemical practice using.

It is a catalytic conversion process where we convert the fat and the fatty acids in the biomass to the biodiesel. So, but our course or this particular module will be focused on these two part, gasification and the pyrolysis. And then when we go to the coal we will see that this coal gasification is the pathway for the getting this hydrogen.

So, moving next into the looking into the biomass composition which can give us a different form of energy so, this we have to look into the perspective that not all the type of biomass can be used in all the process that we discussed in this last slide. So, when we also know that for biogas generation, animal excreta is the major source or feedstock for your biogas generation.

But why do not you put or what will happen if you put a wood pieces or the forest waste, dried leaves, broken branches coconut shells, which are all waste and biomass put it into a biogas plant what will happen? Will you get gas? Maybe, no. So, many of these process are actually very selective in nature.

(Refer Slide Time: 21:23)



And when we look into typical biomass or woody biomass then our cellulose hemicellulose and lignin are major component. Major component of the woody biomass and rest other makes around 5 to 13 percent. So, there are many other things like when we talk about fats and proteins they also make the major thing, but very specific like if you have seeds like say mustard seed or peanuts they will have very high content of fat.

Some fruits will have a high content of protein or the fats or the sugars, but if you look into the totality of a plant, your major component will be this cellulose, hemicellulose and the lignin part. And this cellulose is basically for your biogas generation and the simple part of that like simple sugars are used for bio ethanol generation.

So, typically cellulose which we as a higher animal, cannot digest cellulose. So, these tough molecules we do not have enzymes to digest it. So, our excreta, by-product of our digestive system are very rich in cellulose and that is being used for biogas. But when we look into the bio ethanol they need very simple sugars they want they will not be able to digest cellulose and simple sugars are the broken down product of your cellulose.

So, even if you feed agriculture waste into your bio ethanol plant they will not be able to digest it unless you have this second generation bio ethanol refineries and all, but yeah we will not go into the details of that, but typically I just want to stress on the point that when we look into these pathways the different pathways are very much selective in the nature of your how about type of biomass material can be fed for this particular system.

So, this one biogas this is cellulose when we look into the bio ethanol it is mainly the simple sugars. When we look into this chemical pathway, so, this is fats. So, it will be the fats which will be converted to biodiesel using the chemical pathway. The limitation of the thermo chemical is only it should be dry. As we know does not matter how much cellulose semi cellulose or lignin it has you know that if it is a dry wood you can burn it.

But if it is having very high content of your water just say that you have cow dung. Cow dung is a good source for your biogas generation, but it has almost 70 to 80 percent water content. Will you be able to fire it? No, until unless you dry it to a reasonable moisture level. So, you have this dry dung cakes, dry dung cakes that is also used as a fuel in many of the rural kitchens, which will have a moisture level of less than 20 percent or so. You will be able to burn it easily.

So, that is the limitation of your thermo chemical process, but rest of the process they have a very selective nature of what type of fuel you can get. And you always keep in mind about this lignin this cellulose and hemicellulose this lignin again we will come back when we discuss about the origin of coal and that will be a sort of very interesting thing, but what was the purpose of lignin and how our coal is mostly derived from your lignin part.

But anyway we will continue with that and with this classification. So, I will just end this particular first module. So, what we have understood in this particular first module is the source of biomass how we classify it as green source or the sustainable source or the carbon neutral source. So, this is very important when we look into this we are not only concerned about the process, but also the origin of the feedstock from where we can get potential hydrogen.

So, when we look into the biomass and the coal these two are quite separate biomass we see it as a green source or the renewable source, but we have to be a little bit careful energy plantation and your waste. So, these two are two different verticals. So, if we are looking into waste, waste to any hydrogen production then, yes, it is carbon neutral it is green it is renewable it is sustainable. But when we look into energy plantation that yes, we have to ask 100 questions before we say yes it is sustainable.

So, we will have to have this perspective then we look into the different verticals of the biomass conversion process and among that process we have this thermochemical process; gasification and pyrolysis, which we are targeting to understand which gives us hydrogen.

And then this composition wise what is the typical composition and this is important to understand that our gasification and pyrolysis which are thermo chemical process are independent of these.

But they have a limitation of the moisture level. The moisture level should be less it should be reasonably dry. So, that it can be used effectively and efficiently. So, with this part I would like to conclude this 1st module and we will continue with the next module in understanding the thermochemical conversion process gasification and pyrolysis.

Thank you.