Biomass Conversion and Biorefinery
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Lecture 02
Need for Biomass based industries

Good morning students. This is lecture 2 our course. So, in this lecture, today we will discuss about the need for the Biomass based industries under a biorefinery concept. Before discussing (about) the biorefinery, we will try to understand the basics of biomass.

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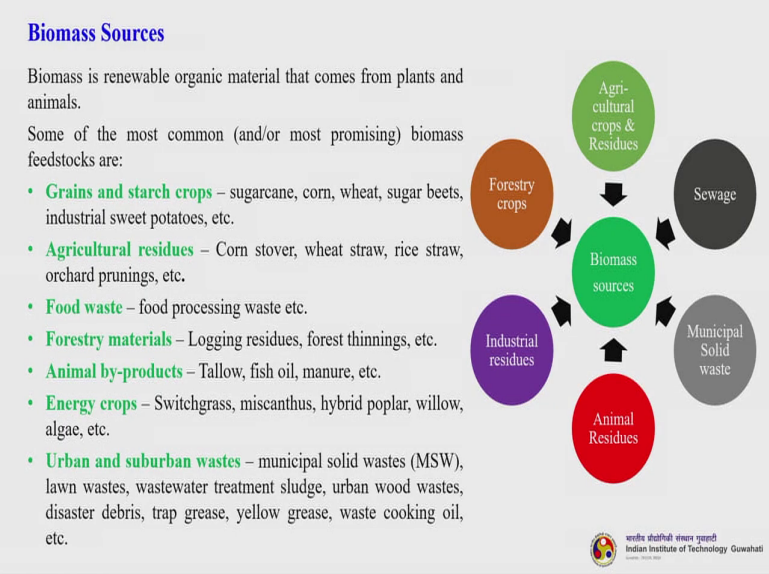

So, you know Biomass is a renewable organic material, usually which comes from plants and animals. So, some of the important or most common (or you can say may be promising) Biomass feedstock are: grains and starch crops such as sugarcane, corn, wheat, sugar beets and sweet potatoes etc.; agricultural residues (such as) corn stover, wheat straw, rice straw and all these things. Then there are food wastes, basically, coming from the food processing industries; Forestry materials (such as) logging residues, forest thinnings; then we have animal by-products (such as) Tallow soil, fish oil, manure etc.

Then we have dedicated energy crops, (which are specific energy crops); some of them are switchgrass, miscanthus then we have a poplar, willow etc and of course Algae. Then, Urban and Suburban wastes. Under this MSW comes (Municipal solid waste), lawn waste, wastewater treatment sludge and there are many other things also.

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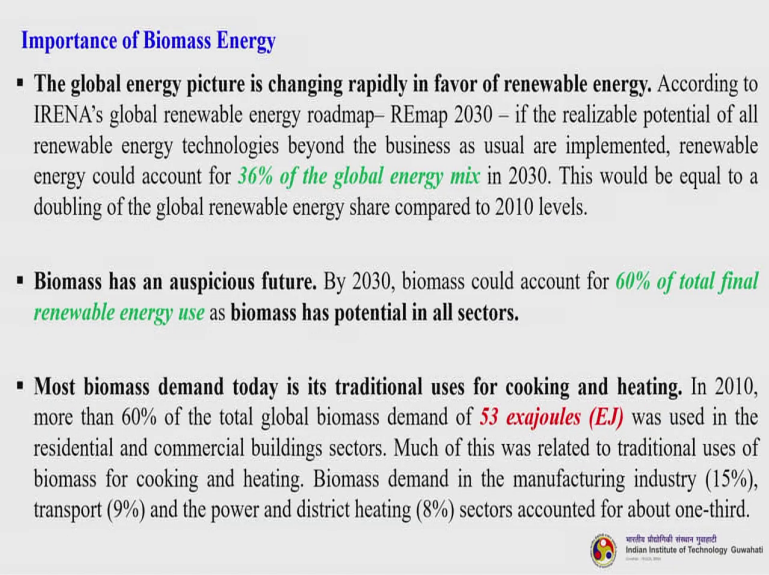

So what is actually the importance of the biomass energy and why we were discussing. Last class (during our introduction) we have understood that what is the importance of biomass based energy and Biomass based industries. So, the Global energy picture is changing rapidly in favour of renewable energy. So, according to IRENA's global renewable energy road map, which is called REmap 2030 - if the realizable potential of all renewable energy technologies beyond the business as usual implement then renewable energy will be accounting for almost 36% of the total Global energy mix by 2030. So if all the governments, according to their policies implement it then this is going to happen. So this would be equal to a doubling of the Global renewable energy share with compared to 2010 levels.

So then biomass has an auspicious future. So by 2030 Biomass could account for 60% of total final renewable energy used as Biomass has potential in all sectors. So Biomass based energy and other value added chemicals or value added products can be used across all sectors. So that is the beauty of biomass actually. So most Biomass demand today is its traditional used for cooking and heating.

As of now also (today) whatever Biomass is being utilised, it is basically (used) for the traditional use (for cooking as well as heating). So in 2010 more than 60% of the total Global Biomass demand of 53 exajoules was used in residential and commercial building sectors. Much of this was related to traditional use of biomass for cooking and heating. Biomass demand in the manufacturing industry is almost 15%, transport sector is 9% and the power in district heating actually it is 8%. So this is almost about one third.

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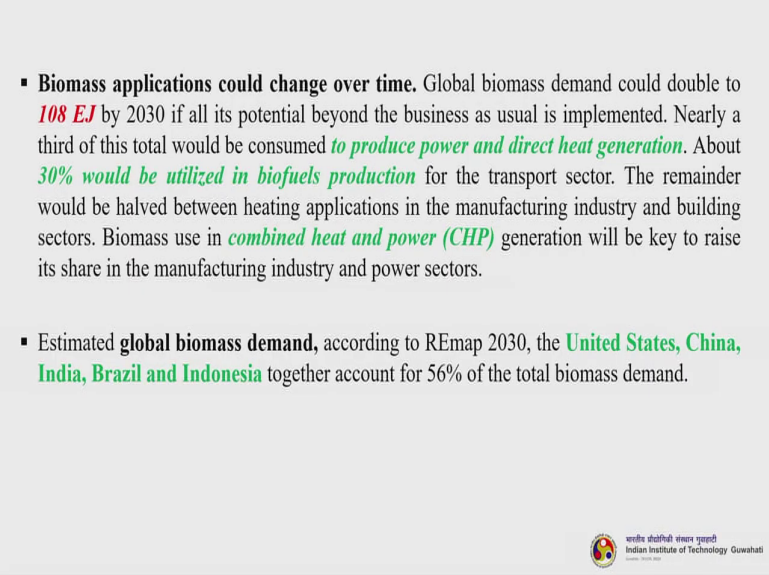

So, Biomass applications could change over time. So, global biomass demand could double to 108 exajoules by 2030; if all its potential beyond the business as well as usual is implemented. So, that means nearly a third of its total will be consumed to produce power and direct heat generation. About 30% would be utilised in biofuel production (mostly for the transport sector) and the remainder would be halved between heating applications in the manufacturing industry and building sectors.

So Biomass use in the combined heat and power generation (CHP technology basically) will be key to raise its share in the manufacturing industry and power sectors. Then, estimated Global Biomass demand according to the REmap 2030, the United States, China, India, Brazil and Indonesia (these are the five countries, which are also five big economies of the world) are going to account for 56% of the total Biomass demand by 2030.

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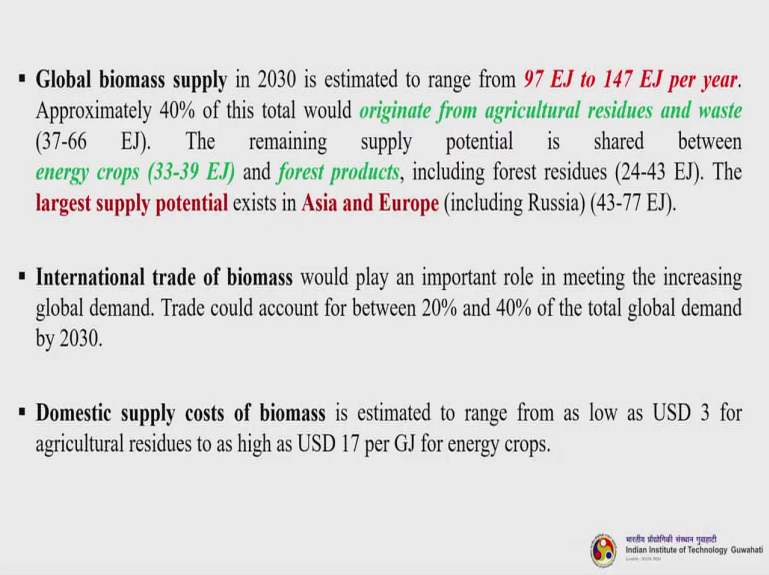

Global biomass supply in 2030 is estimated to range from 97 EJ (exajoules) to 147 exajoules per year. Approximately 40% of this will originate from the agricultural residues. So there lies a very important information about the agricultural and forest residues and waste materials basically. The remaining supply potential is shared between energy crops (33 to 39 exajoules) and forest products including forest residues.

So, the largest supply potential exists in Europe and Asia (including Russia). So this is another interesting thing that, these countries are blessed with huge biomass reserves. So that is why they will be the potential feedstock suppliers basically. International trade of biomass would play an important role in meeting the increasing Global demand. Trade (could) account for between 20 to 40% of the total Global demand by 2030.

Domestic supply costs of biomass is estimated to range from as low as USD 3 for agricultural residues to as high as USD 17 GJ for the energy crops.

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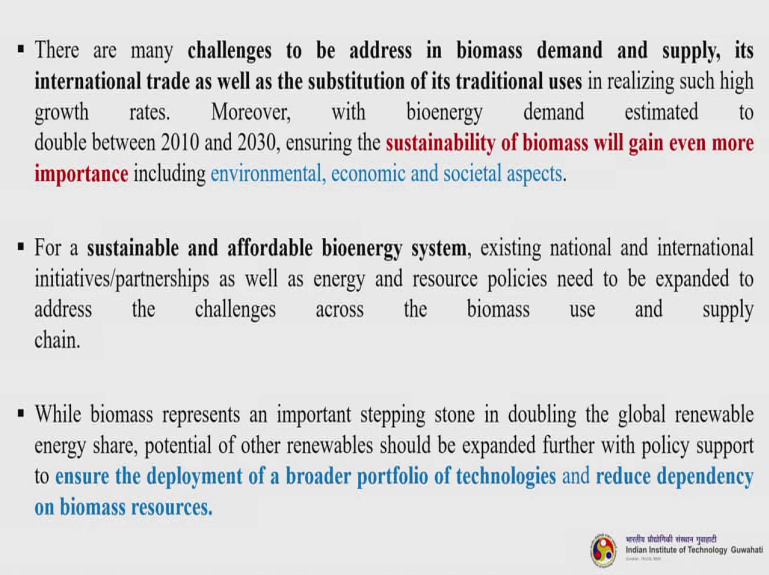

There are many challenges to be addressed in the Biomass demand and supply. Having said that, the biomass and biomass energy is everything it's good for the economy as a biorefinery concept and all; everything is fine, but having said that, we need to understand that there are many challenges that need to be addressed for the Biomass demand and supply. That is the most important bottleneck actually.

So, its international trade as well as substitution of its traditional uses in realising such high growth rates. So, if you keep on using Biomass for cooking purposes and heating purposes, then this is not going to help us in a roadmap; basically if you think about the 2030-2035 road map, which most of the countries have agreed to. So what we have to do is, basically the bioenergy demand is estimated to be doubled between 2010 and 2030, ensuring that sustainability of biomass will gain even more importance including environmental, economic and societal aspects.

Now, for a sustainable and affordable bioenergy system, existing National and international initiatives and partnerships as well as energy and resource policies need to be expanded to address the challenges across the Biomass use and supply chain. Now, while biomass represents an important stepping stone in doubling the Global Renewable Energy share, potential of other renewable energy sources basically should be or must be expanded.

It should be an integrated approach rather than only Biomass and Biomass; that is not going to help in a sustainable way, right. So for that we need to expand our work on our

government policies including subsidising many of the installation facilities, transportation and of course, the tax will also come into picture.

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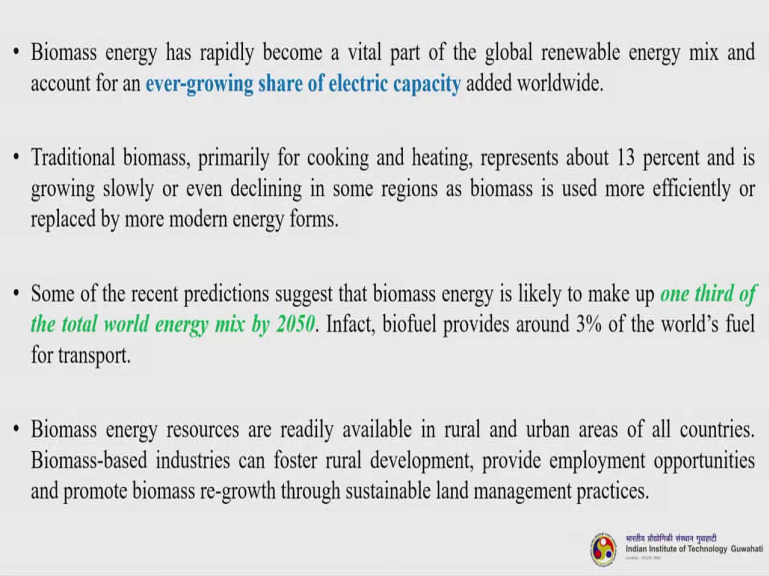

Biomass energy has rapidly become a vital part of the Global renewable energy mix and account for an ever growing share of the electric capacity added worldwide. So, now most importantly (last class also we have discussed that) Biomass based electricity generation is directly feeding into the grid. So these are the upcoming things that has happened. It is happening in many countries and will happen in India too very soon.

So, traditional Biomass primarily for cooking and heating represents about 13% and is growing slowly or even declining. The declining is a good thing for it, but declining in the traditional uses as well as their use in more sophisticated modern Biomass based industries, is going to help us. So, some of the recent predictions suggest that biomass energy is likely to make up one third of the total world energy mix by 2050.

In fact, bio fuel will provide right now almost 3% of the world's total fuel for Transport (liquid fuel basically or maybe some gaseous fuels). So, biomass energy sources and readily available in rural and urban areas of all countries. Biomass based industries can foster rural development, provide employment opportunities and promote biomass regrowth through sustainable land management practices.

This is another important thing. Let us understand, that we talked about dedicated energy crops like as I told you maybe poplar, it may be switch grass, miscanthus, whatever it is. For

that, when I need to cultivate them, I need to grow them, I need to plant them; so where do I plant? So, the available land for agriculture is decreasing day by day across the world due to more and more urbanisation. We know this. It is happening in the in India also. But we need to understand that when I wish to grow this type of energy crops, I should not use our prime agricultural lands, rather, I will use such land which are barren or not suitable for growing the food crops. We can use (those lands) with a little modification, upgrade them and use for these energy crops.

Then things will be very nice. Otherwise, sustainable Land management issue will come into picture.

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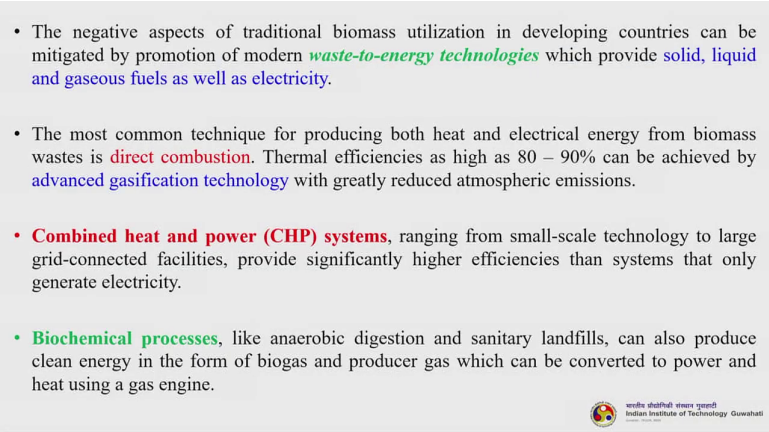

So, the negative aspects of traditional Biomass utilisation in developing countries can be mitigated by promotion of modern waste to energy technologies which provide solid, liquid and gaseous fuels as well as well as electricity. Another hot topic nowadays, is about conversion of the waste to energy. You might have heard about this waste-to-energy many times. There is another term is called water energy Nexus that also is very upcoming.

So let us talk about waste to energy. So most of the wastes of Biological nature can be converted into energy. Now, having said that, there is one technology (of course we will discuss in detail in one of our lectures later when we discuss about the thermochemical aspects). So I will just tell you in a nutshell. Thermochemical conversion technologies; one such is gasification, then we have pyrolysis. These are beautiful Technologies. If we adapt that, we get three different types of bio fuels. One is the liquid bio fuel, one is solid bio fuel and other is a gaseous biofuel. So these technologies are available. Only we need to upgrade ourselves to suit a particular feedstock or rather, I can say that technology should be

developed in such a way that they can process multiple feedstock. That is the challenge basically. So the most common technique for producing both heat and electrical energy from Biomass wastes is direct combustion.

Thermal efficiencies as high as 80 to 90% can be achieved by advanced gasification technology with greatly reduced atmospheric emissions. Then of course CHP is there (the combined heat and power system) ranging from small scale technology to large scale grid connected facility. This is what I was telling you; just technologies are available. And now what is the emphasis is given on? Emphasis is mostly given on how to generate electricity from Biomass and connect it to the grid.

So, biochemical processes like anaerobic digestion and sanitary landfills can also produce Clean Energy in the form of biogas and producer gas, which can be converted to power and heat using a gas engine.

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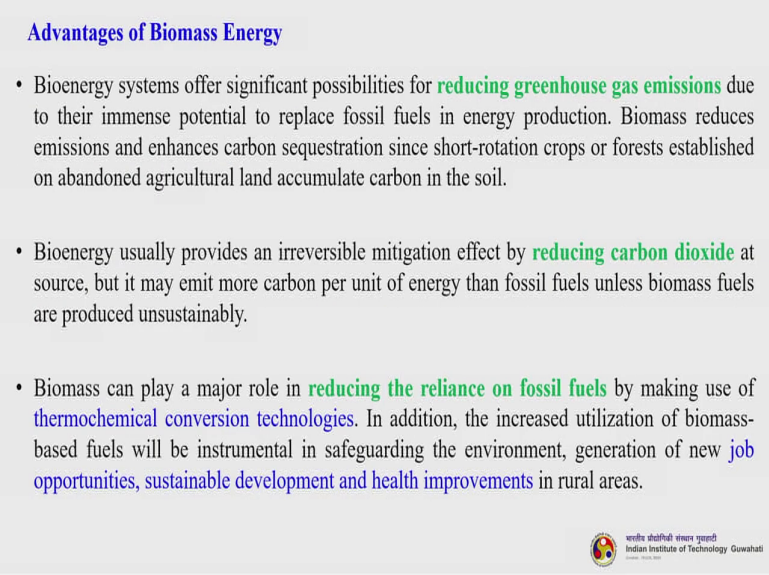

Now let us talk about what are the advantages of biomass energy. So, bioenergy systems offer significant possibilities for reducing greenhouse gas emissions due to their immense potential to replace fossil fuels in energy production. Biomass reduces emissions and enhances carbon sequestration, since short rotation crops or forest established on abandoned agricultural land accumulate carbon in the soil.

So this is also very interesting. That is because we know that biomass is carbon negative. The reason is that, let us say, whatever carbon dioxide we generate by burning fuel even if it is a

biofuel, that goes to the atmosphere. Again, we say that this carbon dioxide will be utilised by the same feedstock materials when you are growing them. Basically it can be any energy dedicated energy crops or any plants or maybe forest as a whole.

So, that is how the carbon cycle is supposed to be managed. And bioenergy usually provides an irreversible mitigation effect by reducing carbon dioxide at source, but it may emit more carbon per unit of energy than fossil fuels, unless, Biomass fuels are produced unsustainably. So this is what we again need to understand that unless and until we produce Biomass based fuel in a huge quantity, what will happen is that, we will be end up in producing more carbon dioxide than we are consuming.

So biomass can play a major role in reducing the reliance on fossil fuels by making use of thermochemical conversion Technology. I just mentioned about it (of course we will discuss more in our subsequent lectures). So in addition, the increased utilisation of biomass based fuel will be instrumental in safeguarding the environment, generation of new job opportunities, sustainable development and health improvements in rural areas.

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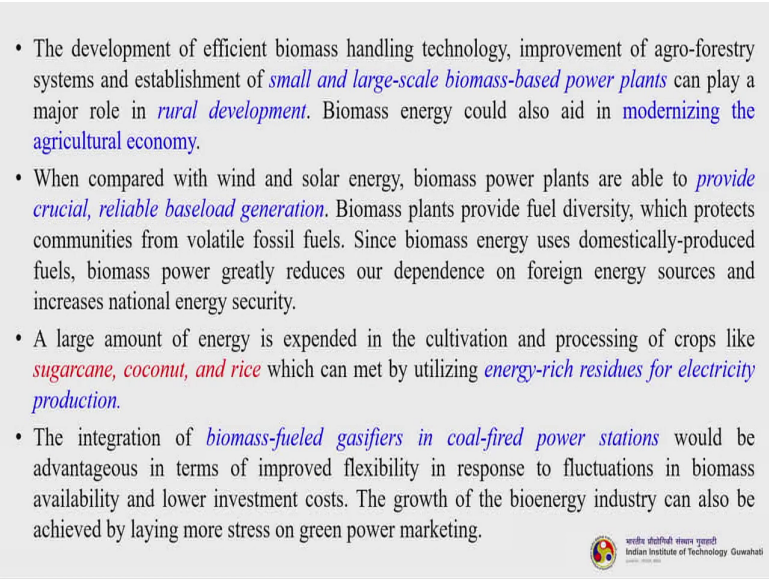

The development of efficient Biomass handling technology, improvement of agro-forestry systems and establishment of small and large scale Biomass based power plants can play a major role in rural development. So another important thing we need to understand is that, the collection of such agricultural and forest wastes for the Biomass based industries is not that easy. So rural people can be engaged for doing that. And there are many concerns about the

transportation of such wastes to a plant where we will convert them basically to liquid and gaseous fuels or generate electricity.

So, if we can locate the plants very near to the rural areas or the forests where these materials are being collected, then it will be a win-win situation. So, we will save a lot of money in transportation as well as the rural people will get some jobs and there will be some community development also. So when compared with wind and Solar Energy, Biomass power plant cell able to provide crucial, reliable based load generation.

This is more important. This is basically when we are talking about connecting to the grid. There should be a proper sustainable supply. Otherwise, what will happen, today where you are supplying one particular rate, tomorrow it will fall; that is not going to help in a sustainable way when we talk about grid connectivity. So biomass plays a better role with respect to wind and solar. So a large amount of energy is expended in the cultivation and processing of crops like sugarcane, coconut and rice, which can be met by utilising energy rich residues for electricity production.

So some of these processing, you know, use huge energy; sugarcane, coconut, rice mills (all these things). So what is being suggested is that, there is a sugarcane waste, which is called bagasse, then there is coconut waste, there is rice straw (all these wastes), if these wastes which are generated at the site can be converted using suitable technologies to heat or energy, or any such thing and maybe electricity or may be a small scale gasification plant; it can save a lot of money basically.

So basically, it is an integrated approach. So, the waste generated at the source and treated and converted in the same source to a value added product or you can say that, maybe to energy. That approach will help us a lot. The integration of biomass-fueled gasifiers in coal fired power stations would be advantages in terms of improved flexibility in response to fluctuations in Biomass availability and lower investment costs.

So if you couple Biomass fueled gasifiers along with coal fired power station; it will help us with 2 things; first is that, it will address the (issue of) availability of the Biomass around the year, because coal is available to generate power. Second thing is that, we will reduce use of coal thereby reducing the carbon dioxide generation.

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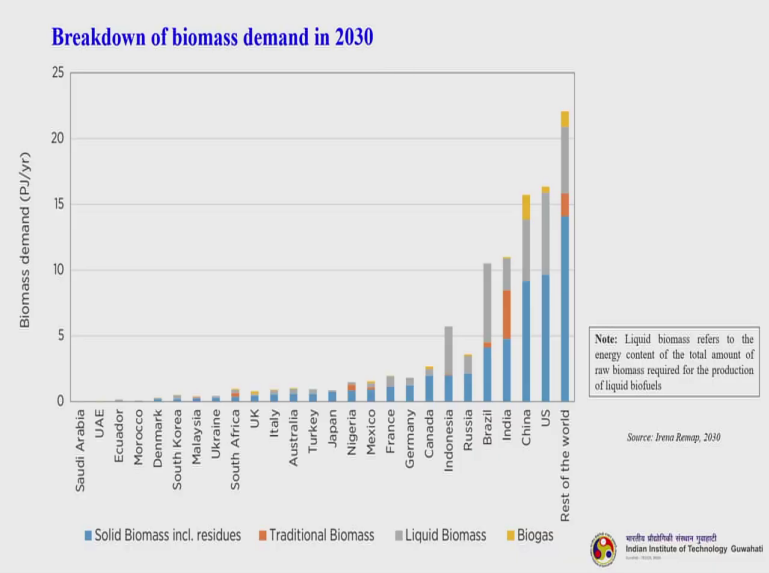

So, look at this particular biomass demand plot. This is extrapolated till 2030. Just look at the last; look at these studies: Indonesia, then Russia, Brazil, India, China and United States. So, these six countries mostly, even if you can consider Canada also, but I am counting these 4 to 5 countries. So just look at this particular plot. You can see that United States, China, India and Brazil, these are the four major contributors or let us say that their demand for Biomass is more compared to the rest of the world.

Because these countries have huge biomass reserve, as well as, they have realised the potential of the biomass based fuels and energy and of course industries also.

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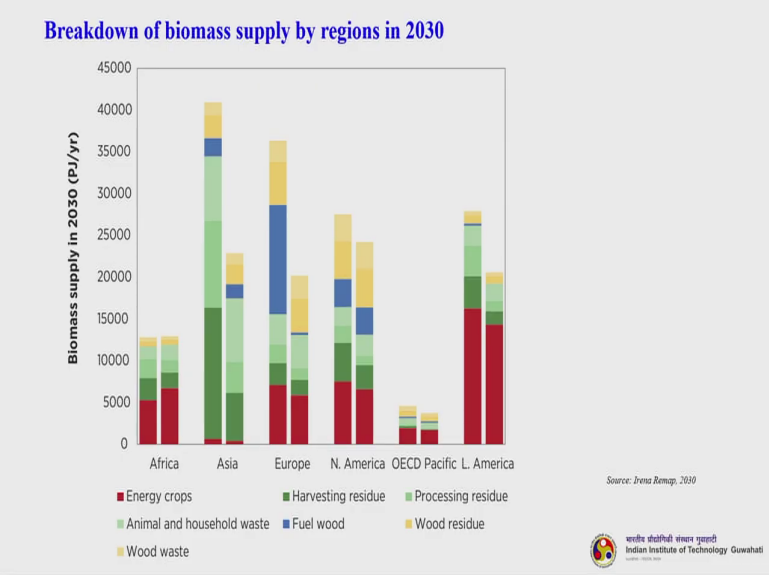

So, this is (breakdown of biomass supply) by region. Again you see Asia, the huge one here. Basically, the contribution is coming mostly from China, India and Indonesia; then Europe North America (in North America United States only) and then Latin America is also there. So mostly it is coming from harvesting residues here in Asia (in which India falls). Then we have processing residues, and of course we have fuel wood, wood residues as well as wood waste.

Energy crops (share) is very less in Asia. However, it is so high in Europe, America and other countries because they have started cultivating the dedicated energy crops. We are slowly adopting it.

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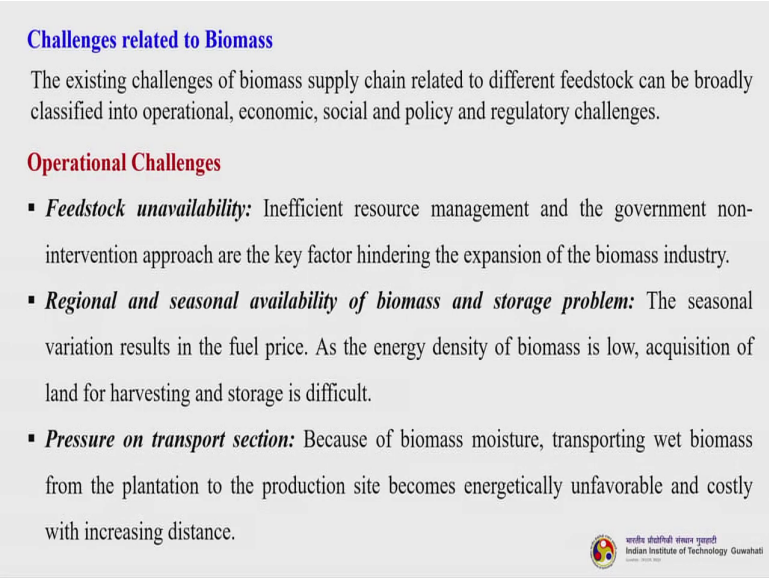

Then, having said about the Biomass based industries, the advantages of bioenergy and all these things; let us now understand what are the challenges related to Biomass. So the existing challenges of biomass supply chain related to different feedstock can be broadly classified into four things or five things. First is operational, then economical challenge, then social and policy and then regulatory challenges.

We will see one by one. What are operational challenges? So, feedstock unavailability; Inefficient Resource Management and the government non-intervention approach are the key factors hindering the expansion of the Biomass industry. Feedstock of biomass should be in such a way that it should be available in a sustainable way throughout the year, but, can we ensure that? Let us understand that; I am talking about rice straw or say bagasse. These are seasonal crops. Any such crops that are seasonal, we need to understand that, of course their

generation of waste is also seasonal. So, can we produce so much of waste, so that we can keep it or store it for round the year application? The answer right now is, no. At least for the Indian context, but, we need to work on that. There are policy matters, government should interfere and make policies in such a way. And there should be Technologies, developed in such a way that we can store these wastes for long-term use (right now that is not happening).

So, regional and seasonal availability of biomass and storage problem; this is what I already told you. Then, pressure on transport section. Because biomass contains a huge amount of moisture, that is why transporting waste biomass from the plantation to the production site becomes energetically unfavourable and costly with the increase in distance. Basically distance between the collection side and the plant.

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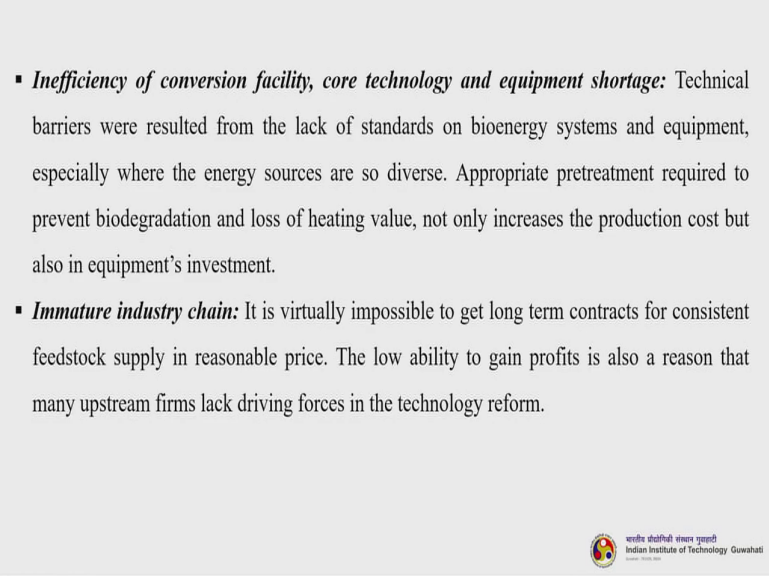

So then, inefficiency of conversion facility, core technology and equipment shortage; now technical barriers were resulted from the lack of standards on bioenergy systems and equipment, especially where the energy sources are so diverse. Appropriate pre-treatment required to prevent biodegradation and loss of heating value not only increases the production cost, but also in equipment's investment. So there is something called pre-treatment which we will discuss in our subsequent lectures, what is pre-treatment and what is the importance of it. So, we need to pre-treat the biomass according to where they are going to be used, whether it is going to be in the thermal conversion technology or biological conversion technology. So, depending on that we need to pre-treat the biomass. Basically fractionation and size reduction and there are other things also.

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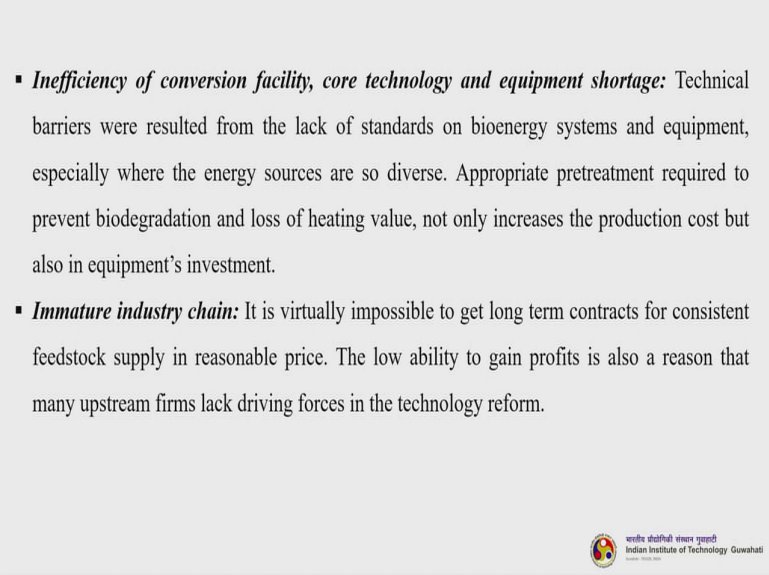

So then, immature industry chain; so, it is virtually impossible to get long term contracts for consistent feedstock supply in reasonable price. So, industry will only be interested, if I am going to supply them throughout the year in a sustainable way (the particular feedstock; everybody is interested in a particular feedstock). So, that is not going to happen, right? But policies should be framed and it should be implemented in such a way that industry are favoured by implementing such techniques.

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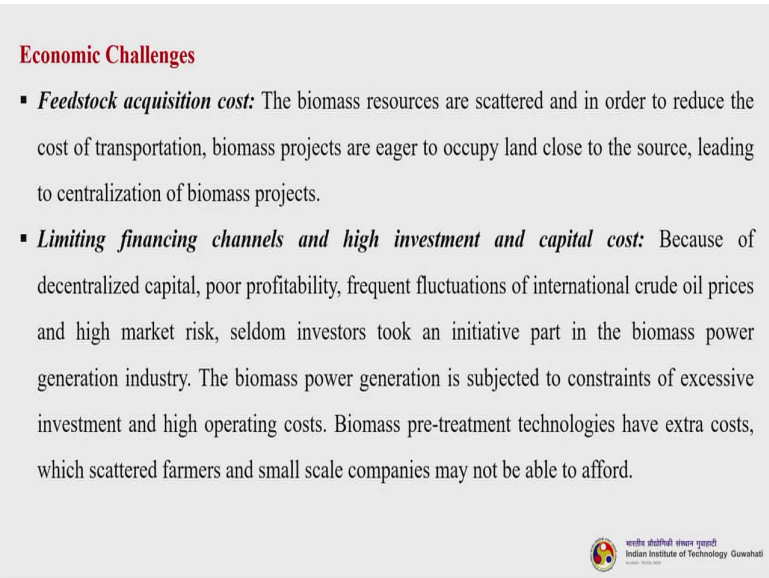

Then economic challenges; so feedstock acquisition cost; the Biomass resources are scattered and in order to reduce the cost of transportation, biomass projects are eager to occupy land close to the source, leading to centralisation of biomass projects. Then, limiting financing channels and high investment and capital cost; as of now, the industries which are implementing them, I can tell you that, there is a huge cost which is required basically for the

capital investment; for procuring the equipment, installation, the land cost (forget about the running cost and manpower cost). So here, the government has to intervene and make policies in such a way that there will be GST credit, and there will be less tax on procuring equipment. And of course there are other things apart from the subsidies.

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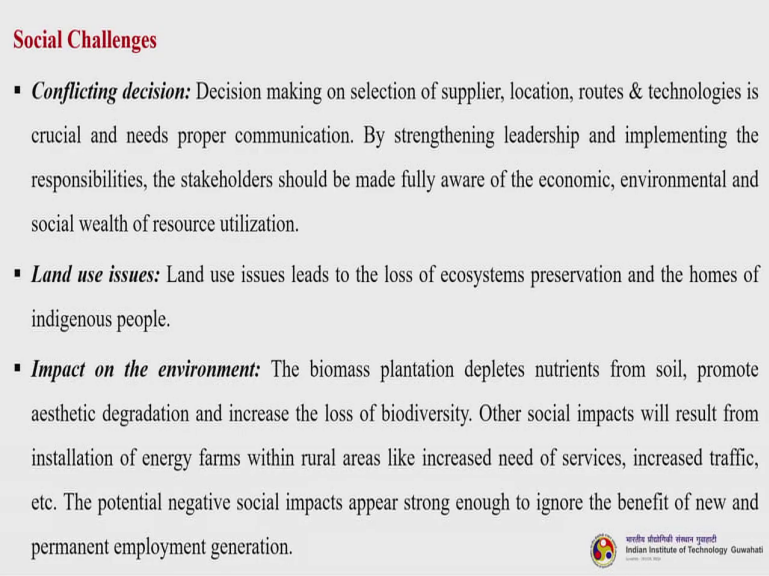

Then social challenges; so, under social challenges there are a few things. First one is the conflicting decision: so, decision making on selection of supplier, location, routes and technologies is crucial and needs proper communication. So basically, which supplier you are going to choose, whether it is reliable or not, where it is located, where is my plant located, what are the routes or distance, how much it is going to cover for the transportation of the feedstock from the procurement site to my plant and technologies.

So, we need to have a proper decision making system for that. So, land use issues: land use issues lead to the loss of ecosystem preservation and the homes of indigenous people. That is why I was just mentioning that, we should use such lands which are not at all used for the dedicated food crops.

Then; impact on the environment: The Biomass plantation depletes nutrients from the soil, promote aesthetic degradation, increase the loss of biodiversity. Other social impacts will result from installation of energy farms within rural areas, like increased need of services increased traffic etc. The potential negative social impacts appear strong enough to ignore the benefit of new and permanent employment generation. So, if we try to develop a rural based bio economy, then most of these issues will (should) be addressed.

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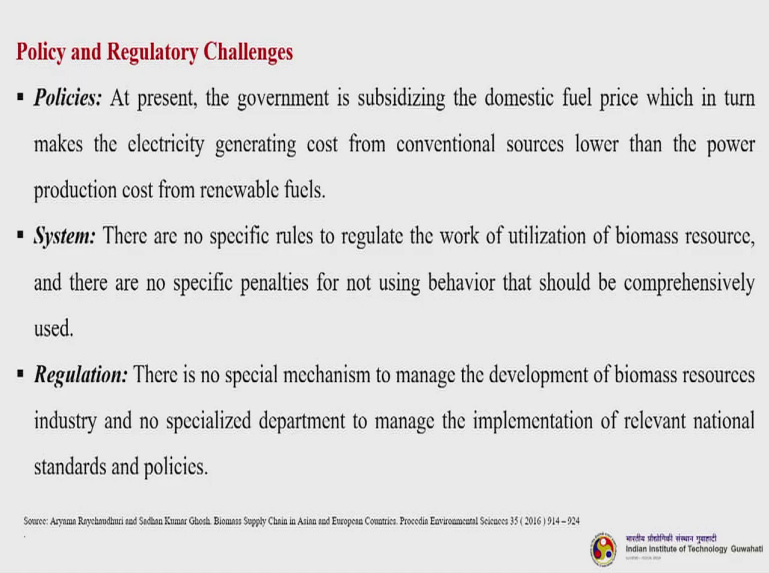

Then let us talk about the policy and regulatory challenges. At present the government is subsidizing the domestic fuel prices which in turn makes the electricity generating cost from conventional sources lower than the power production cost from Renewable Sources. This is exactly what is expected from the governments. Not only from the Government of India but from the governments of the all other countries also; that they are doing it.

So, there are no specific rules to regulate the work of utilisation of biomass resources and there are no specific penalties for not using behaviour that should be comprehensively used. So basically policy guidelines should be there. Governments should come up with clear cut policies and guidelines; what is to be done and what is not to be done. If you are doing something which is not expected, it will result in Environmental concerns on social concerns. Then, you need to be penalized. As such, now such policies are not available. But I know that there are coming. Soon it will be implemented in India as well as other countries also. There is no special mechanism to manage the development of the Biomass resources industry and there is no specialist department to manage the implementation of relevant national standards and policies.

So all these things come under the government. These are governments' job, basically. So I know the government actually is coming up with so much of policies for the Biomass based industries and there are already some existing policies, but, more needs to be done and it is being done actually.

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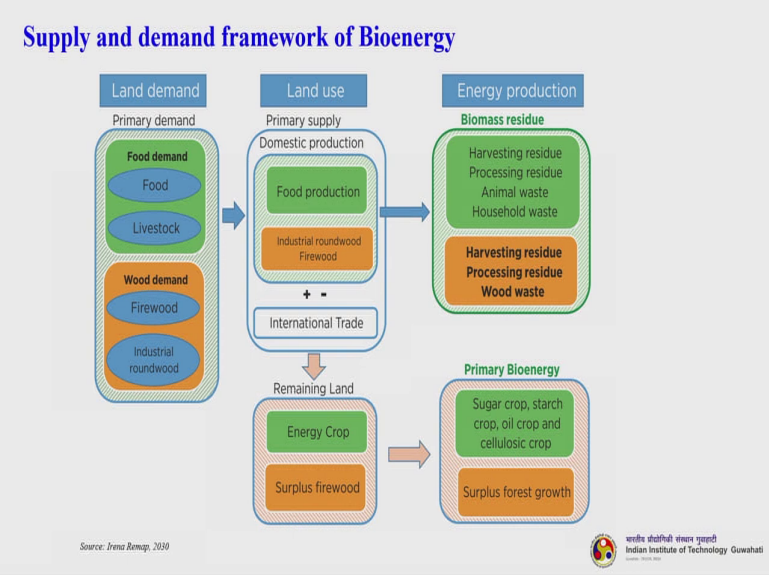

Let us now understand the supply and demand framework of bio energy. You can see this particular slide, how it is being actually depicted here. So, the land demand, land use and energy production. So, land demand in all countries is basically based on the food demand; for growing the food crops and of course (also) for wood demand; that means it is for either the industrial demand for forests.

So when we talk about (land) use; so the domestic production is basically for the food and industrial firewood and all these things plus international trade. And then, the remaining land should be utilised for the energy crops and surplus firewood. And the energy production from the Biomass residue, harvesting residue, processing residue, animal waste, household waste etc.

Then primary bio energy will come from these dedicated energy crops such as sugarcane, starch, oil crops and other cellulosic crops.

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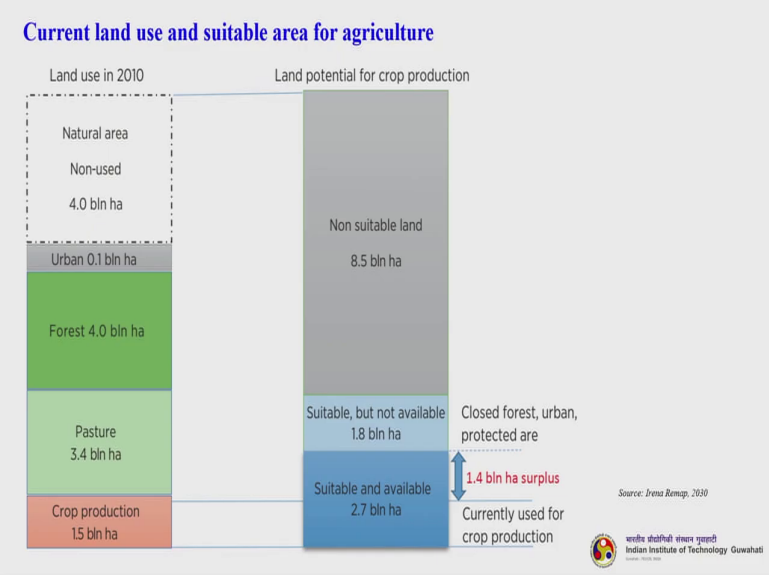

So, if you look at the current land use and suitable area for agriculture. So this is the land use in 2010 and that one is the potential for the crop production. So you can see that, right now the forest is 4 billion hectares, then crop production is going on in 1.5 billion hectares. And here, we were talking about the projection, suitable and available area that will be basically for the dedicated energy crop production or biomass production; it will be almost around 2.7 billion hectares. So there will be a 1.4 billion hectares of surplus available land that can be utilised.

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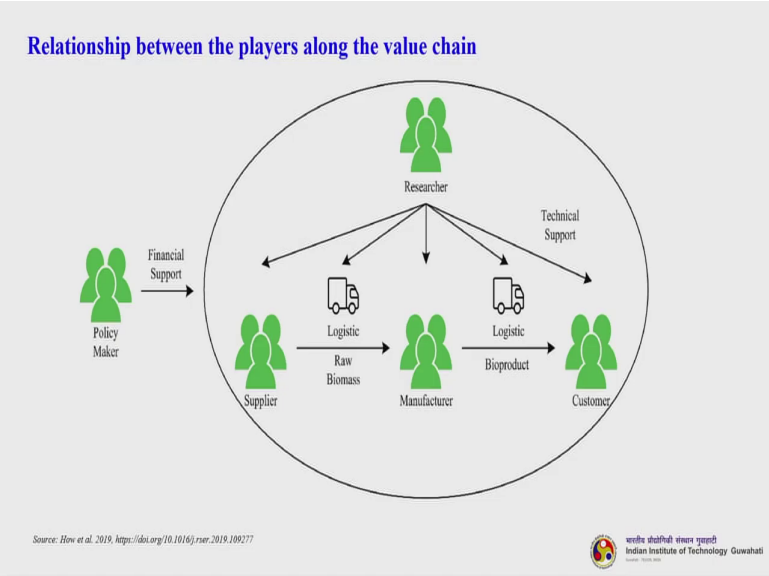

So let us understand the relationship between the players along the value chain. This is very interesting and very important, where you can understand that every one of us has a role to play in this business. So all the policy makers, they will decide the policies. They may give financial support and all these things. Then there is something called a researcher. Where

people like me and some of you are coming into picture. What they do is, they are involved or integrated into various sectors, whether it is a supplier, whether it is the manufacturer, whether it is a customer.

Researcher has a big role to play in every sector. So then there is Logistics for raw Biomass storage and transportation, and there is Logistic which is related to the bio products, (processed products basically) for transportation and to take them to the reach of the common people or the customers. So the researcher has a lot of role to play in the entire system; this Biomass based industry and processing industries sector.

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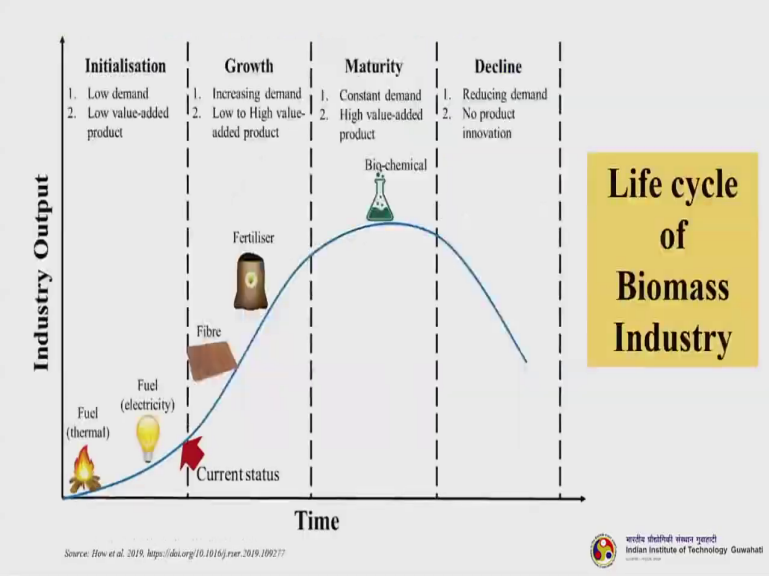

Let us talk about the life cycle of biomass industry. Please see where we are heading, we are now here in the current status. You see the red one here. So that is between the initialisation phase and the growth phase (I am talking especially about India). So we have started from the fuel from the thermal energy sources (and) electricity. Electricity has been implemented hugely in our country. Still there are many villages in rural areas where the electricity has not reached.

It is going to be implemented very soon. Government of India is doing that. So then, we move to the growth phase. In growth phase what is available? So basically there will be increasing demand (of electricity or you can say energy) due to urbanization and industrialization and there will be low to high value added products that will come into picture when we pass from the initialisation phase to this particular growth phase.

So, those products can be fertilizers, fibres, platform chemicals or other value added products. Then we go to the maturity and decline stage. When you go to the maturity stage, we have a constant demand. Now our demand is basically increasing. The moment you reach here, there will be a plateauing effect and we will have a constant demand because you have reached a mature stage.

And more or less our industrialisation or let us say the urbanisation has saturated. So, we go for very high value added products like biochemical. Then after that there may come a decline stage where there will be a reducing demand. And there will be no more product innovations happening.

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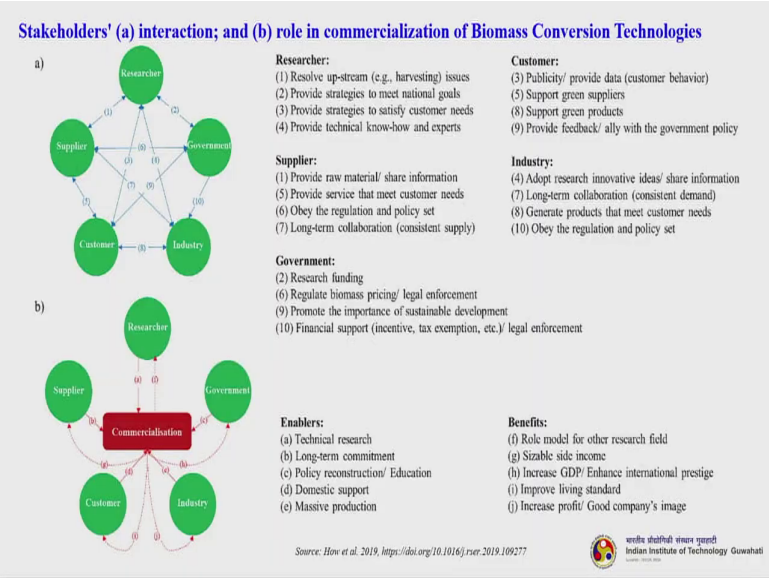

So here, this is the stakeholders' interaction and role in commercialization of biomass conversion technologies. So, in one of the slides; just 2 slides back we have discussed how researchers are playing a role. Here also, you can see that the researchers in the top one you see there. How they have integrated themselves into various other people basically the supplier, customer, industry and the government.

They have completely integrated themselves along with all other stakeholders. So what do they do? Researchers will resolve the upstream issues or harvesting issues basically. They will provide strategies to meet the national goals as mentioned by their governments. They provide strategies to satisfy the customer needs. And they will provide technical know-how and expert. Then the supplier; what the supplier is supposed to do? The supplier will provide raw material and share information.

They provide services that meet customer need. They will obey the Regulation and policy set and it is the long term collaboration. So, when I talk about long term collaboration that means it's the consistent supply. And what the government will do? The governments' job is to provide research funding. Governments' job is to regulate the Biomass pricing and legal enforcement. Then, a government must promote the importance of Sustainable development and a government should go for financial support, whether it is an incentive, subsidy, tax exemption like GST credit and all these things will be there.

Then there will be customer. So, the customer; what is their job? So, publicity and provide data that (basically feedback, they should give a feedback), support green suppliers, support green products and provide feedback on this (what I already told). And then there is the industry, the most important. So, adapt research innovative ideas and share information, they should have a long-term collaboration (looking for a consistent demand basically), they should be able to beat that demand, they should generate products that meet customer needs and obey the Regulation and policy set. So, you can understand in this particular slide, how all the stakeholders, all of us, you, me, government, the suppliers, the industry people. So, all of us have a role to play as a stakeholder in this particular Biomass conversion business.

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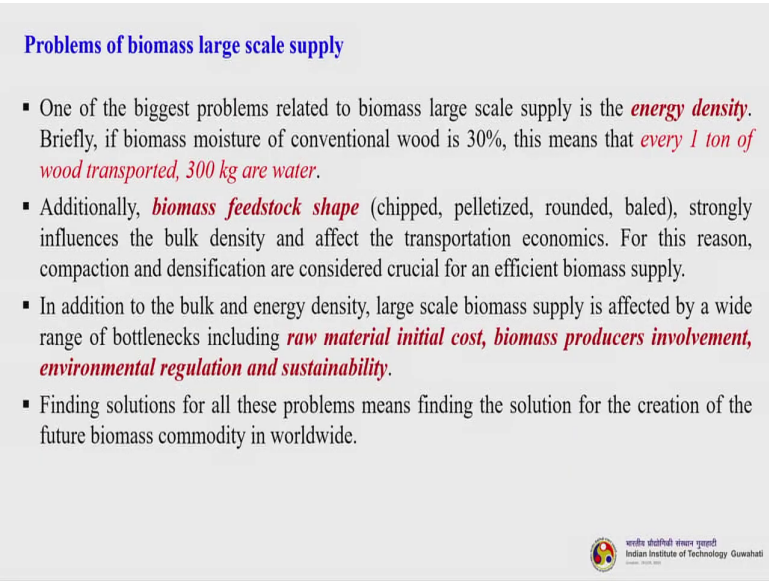

Let us understand the problems of biomass large scale supply. So one of the biggest problems related to Biomass large scale supply is the energy density. Briefly if Biomass moisture of conventional wood is 30%, what it means? It means that every one 1 ton of wood or the Biomass that I transport, I am transporting almost 300 kg of water. So it is huge, it is waste basically and I am paying a heavy price for the transportation.

So additionally, Biomass feedstock shape; so it is also very important. So whether it is chipped, pelletized, rounded, baled, all these things will strongly influence the bulk density and affect transportation economics. So we should also look into that. Then, in addition to the bulk and energy density, large-scale Biomass supply is affected by a wide range of bottlenecks, including raw material initial cost, biomass producers' involvement and environmental regulation and sustainability.

Now, finding solutions for all these problems means finding the solution for the creation of the future biomass commodity in worldwide.

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PROBLEMS	SOLUTION
High quality biomass (wood) is considerable but limited expensive and not always sustainable.	Utilization of agro-forestry residues. High availability and fully environmentally sustainable.
Agro-forestry residues have lower quality and higher micro-elements (K, Ca, Mg, ashes) content.	Blending of different biomass feedstocks to arrange suitable average composition.
Availability is mainly reduced to forests areas.	Residues have much lower costs and dispersed and available almost everywhere.
Low energy density and bulk volume (KJ/m^3) of fresh biomass affect storage costs and transportation efficiency.	First step chipping activities, enhance biomass energy density, increasing transportation efficiency.
Biomass degradability affect large distances transport activities, long time storage.	Agro-pellets production, with low moisture and high energy density. Avoiding degradation and transportation issues.

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So are there are problems (of course), but there are solutions also. So, let us understand what are the problems and what can be the solution. So, high quality Biomass is considerable but limited expensive not always sustainable. So what can be the solution? Utilisation of Agro-forestry residue; that can be a sustainable solution. High availability is there and fully environmentally sustainable.

What is the other problem? Agro-forestry residues have lower quality and higher Micro elements (that is true actually), calcium, magnesium and all these mineral compounds basically. So what can be the solution? The blending of different Biomass feedstock to arrange suitable average composition. So, do not go for a single stock. It is not going to help us in a sustainable way. We should always go for multiple feedstock.

So that is why, the technology should be developed in such a way that, basically our process or equipment or let us say the process itself is capable enough to take (utilize) multiple feedstock. So, because multiple feedstock will have different composition. So you can play around and mix the composition in such a way that we will have an average composition that is good enough for producing the energy or let us say, other value added products.

Availability is mainly reduced to forest areas. Now, residues have much lower costs and dispersed and available almost everywhere. So, if you talk about the municipal solid waste, food processing waste, industrial waste, then the dependence on only forest waste will come down. Now; low energy density and bulk volume of fresh biomass affect storage cost and transportation. This is what we just discussed in the previous slide.

So the activities, what we need to do is that, you go for chipping, enhance biomass storage density, dry them, but again energy is coming into picture. So it is always advisable to reduce the transportation cost. So how do you do that? Locate the biomass industries in such areas where there is a huge biomass reserve. Then biomass degradability affect large distance transport activities, long term storage.

Agro pellets production; you produce pellets from the Biomass and then it is easy to transport, the density will come down (with low moisture and high energy density), avoiding degradation and transportation issues. These are some of the major problems which are associated with the Biomass and what we can and how we can address them suitably.

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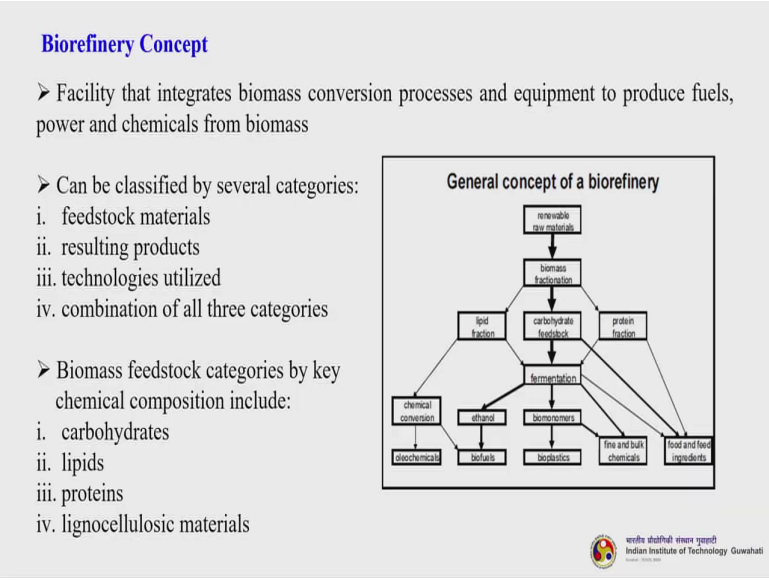

So let us now understand what is a biorefinery? So I will show you 2, 3 slides to understand what is biorefinery, then we will discuss about the Biomass based biorefinery things (concept). So facility that integrates Biomass conversion processes and equipment to produce fuels, power and Chemicals from Biomass is called a biorefinery. So it can be classified by several categories: by feedstock materials, by resulting products, by technologies utilised or a combination of all these three.

So, biomass feedstock; categorised by: chemical composition; maybe carbohydrates, lipids, proteins, lignocellulosic materials.

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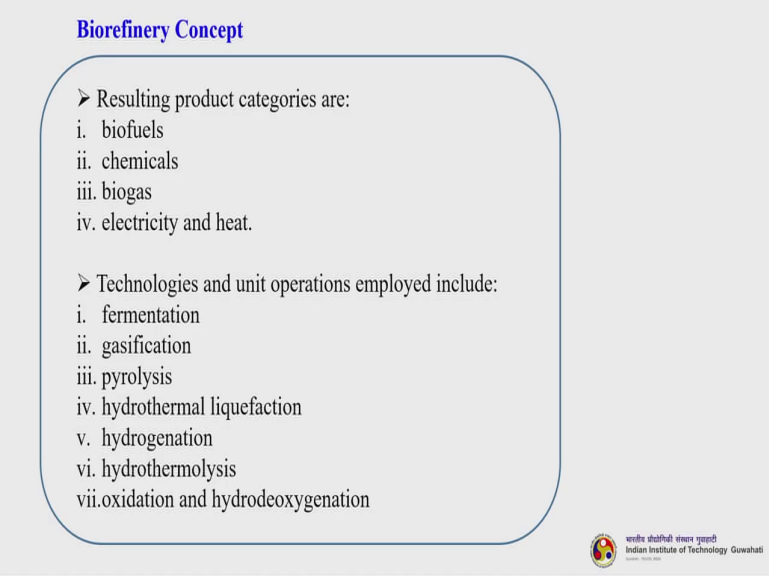

So the resulting product categories may be biofuels, chemicals, biogas, electricity and heat and technologies and unit operations employed include fermentation, gasification, pyrolysis, hydrothermal liquefaction (It is very upcoming technology actually), hydrogenation, hydrothermolysis and oxidation and hydrodeoxygenation.

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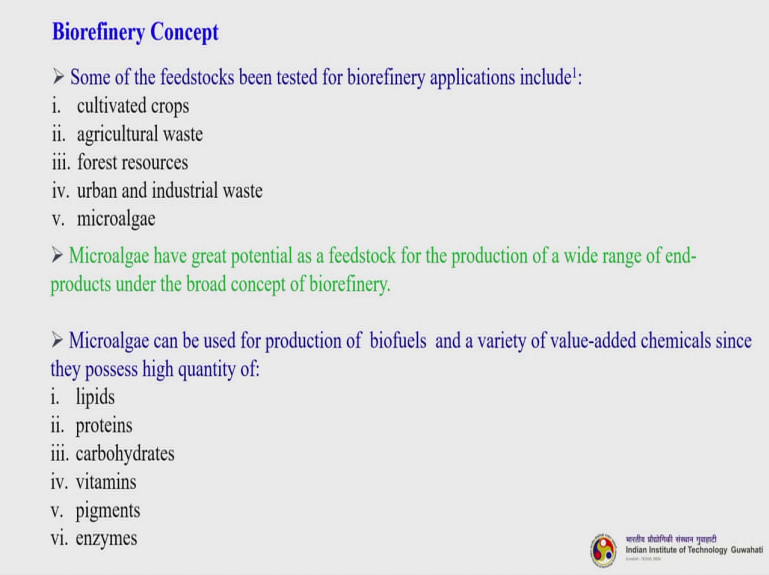

So some of the feedstock that has been tested (and I have just listed few there are many and list is endless basically) are cultivated crops, agricultural waste, forest resources, urban and industrial waste and micro algae. Algae is something interesting. We will discuss about algae letter on; so microalgae have a great potential as a feedstock for the production of a wide range of end products under the broad concept of biorefinery.

Algae can be used for the production of biofuels and a variety of value-added chemicals, since they possess high amount of lipids, proteins, carbohydrates, vitamins, pigments and enzymes.

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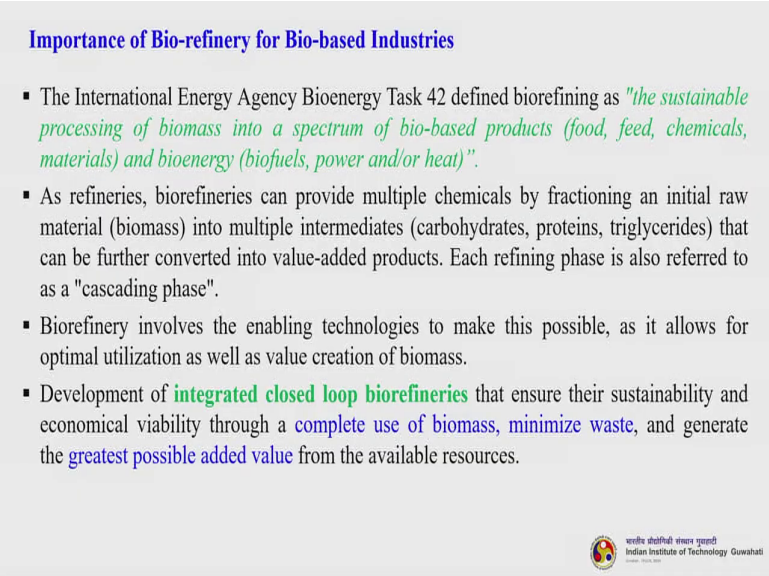

So the importance of bio refinery for bio based industries: The International Energy Agency Bioenergy Task 42 defined biorefining as the sustainable processing of biomass into a

spectrum of bio based products. So it can be food, feed, chemicals and materials, as well as bio energy that means bio fuels, power and/or heat. As refineries, biorefineries also can provide multiple chemicals by fractioning an initial raw material (which is biomass in this case) into multiple intermediates (so it can be Carbohydrate, protein, triglycerides) that can be further converted into value added products. Each refining phase is also referred to as a cascading phase. Now, biorefinery involves the enabling Technologies to make this possible, as it allows for optimal utilisation as well as value creation of biomass. Development of integrated closed-loop biorefineries that ensure their sustainability and economical viability through a complete use of biomass, minimise waste, and generate the greatest possible added value from the available sources.

What is this integrated close bio refinery? Let us say, it is a bio mass based refinery, I am going to use one or two feedstock. I process them. Then I produce electricity or maybe liquid bio fuels or maybe steam (if I am going for some steam based power generation) or some other commodity products or value added products. Now thereby, I also produce a huge amount wastewater because water is required in every stage of processing.

So having said that, you know, the fresh water availability is reducing day by day across the globe in various places. We know that in India also, it is a huge problem in a few areas. So, what is the need of the hour? It is that you have to treat and recycle this waste water in a closed loop system. That means if you do that, we will be depending less on our freshwater resources (that is what is the need of the hour).

Because a time will come when there will be very scarce water available. So how will we run a refining process? Refining process, whether it is a bio refining or Petroleum crude based refining, it consumes huge amount of freshwater. So we should look for an integrated closed loop biorefinery. That means whatever waste we are generating it can be solid waste also. I am not just talking about liquid waste (basically the wastewater), let us not talk about only the liquid. Let us do something about the solid waste also. Whatever solid waste we generate can we further process them to get fuels out of that, or, can we further process them to get some value added products from that? If you do that in a closed to biorefinery circle, then the biorefinery will become economically sustainable and will be a viable option.

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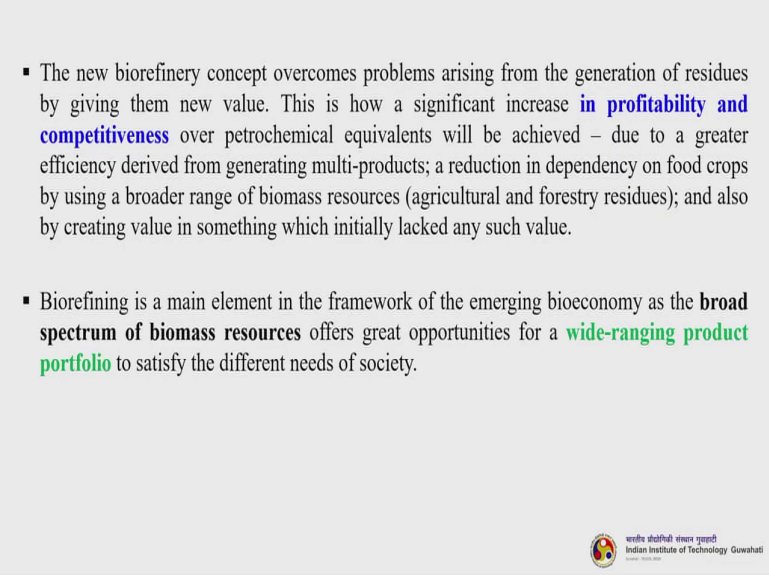

So the new you biorefinery concept overcomes the problems arising from the generation of residues by giving them new value. This is how a significant increasee in profitability and competitiveness over petrochemical equivalents will be achieved. Otherwise petrochemical based fuels and products will always be low cost than whatever we produce from the biomass. So Profitability and Competitiveness has to be taken care of also.

So we go for multiple products. What is the answer for that? We go for multiple products. Do not aim only for the fuels or energy, but you please look for other products also. So, biorefining is the main element in the framework of the emerging bio economy as a broad spectrum of biomass resources offers great opportunities for a wide-ranging product portfolio to satisfy the different needs of society.

So, as I told you, unless and until we go for multiple products, unless until we work for a waste to energy or water energy nexus and how do we convert in-house generated waste from the refining process, whether it is solid or liquid and get some value added products out of that, we are not going to have a sustainable and economically viable biorefinery.

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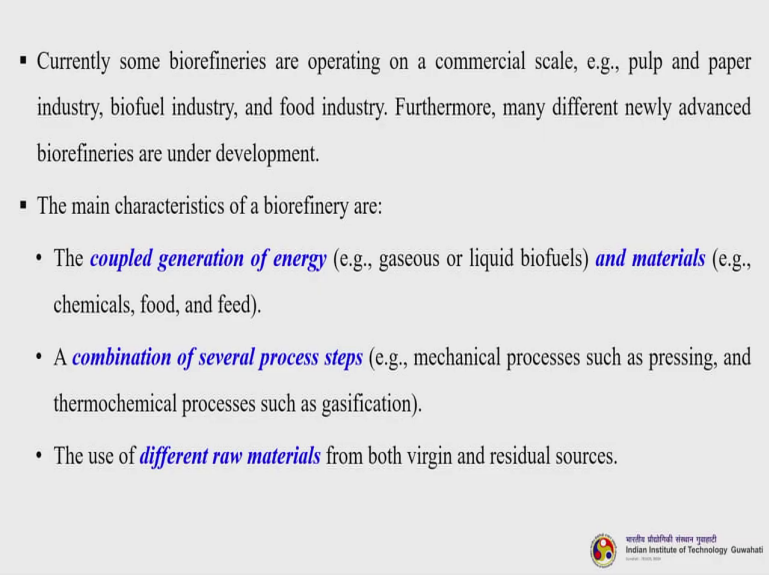

So currently some biorefineries are operating on a commercial scale. Pulp and Paper Industry, biofuel industry and food industry. Furthermore, many different newly advanced biorefineries are under development. So the main characteristics of a biorefinery are: there should be coupled generation of energy (gaseous and liquid bio fuels) as well as materials (it can be Chemicals, food and feed). A combination of several process steps; it can be mechanical processes, it can be thermochemical processes, it can be biochemical processes also.

Use different raw materials; from both virgin and residual sources (that is also very important). A common hurdle in the commercialization of biorefineries it is economic viability. The economic hurdle starts from procuring Biomass and its logistics, technology maturity and policy support. This is what we have already discussed.

So, the rate of commercialization of biorefineries is slow primarily due to the lack of policy support. This I have already mentioned that the government has or should come up with policies which will support the establishment of biorefineries. So biorefineries have to compete with well-established petrochemical products. Policy support can drive innovation, help technology to mature, create competitiveness to a market which in turn could reduce the cost thus making the economic viability of biorefineries a reality. Government as a big role to play.

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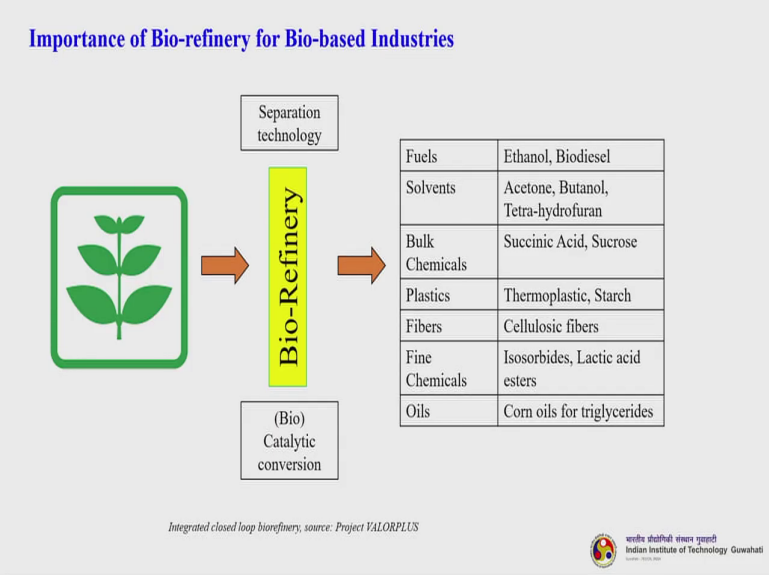

This is how it looks like basically. You have a biomass here, you process in the biorefinery, you have downstream processing, you have separation technology. It can be catalytic conversion or it may not be. Then we get this type of products: fuels, solvents, bulk Chemicals, plastics, fibres, fine Chemicals and oils and what not? You can just see what not we are getting from the biorefinery.

But again, one particular feedstock will not give me like this. So I should go for multiple feedstock. And as well as not only virgin feedstock, but also processing feedstock, processing with.

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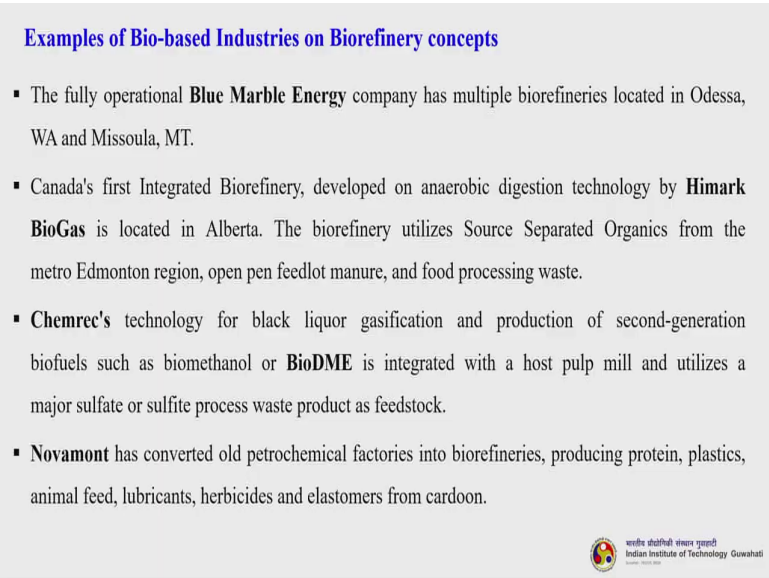

So before I wind up, I just quickly show you. We will glance through the different bio based industries that are actually established and running successfully. Blue Marble Energy, so that

is in Odessa and the Missoula. Canada's first integrated biorefinery, developed on anaerobic digestion technology by Himark BioGas that is in Alberta, then Chemrec's technology for Black Liquor gasification and production of second generation of biofuels such as biomethanol and bioDME. That is integrated with the host pulp mill and utilizes a major sulphate or sulphite process waste product as the feedstock (completely waste product based biorefinery).

Then Novamont has converted old petrol chemical factories into biorefinery. This is a very interesting thing. So by just changing some of the processing things, some equipment, they are running this refinery in a sustainable way.

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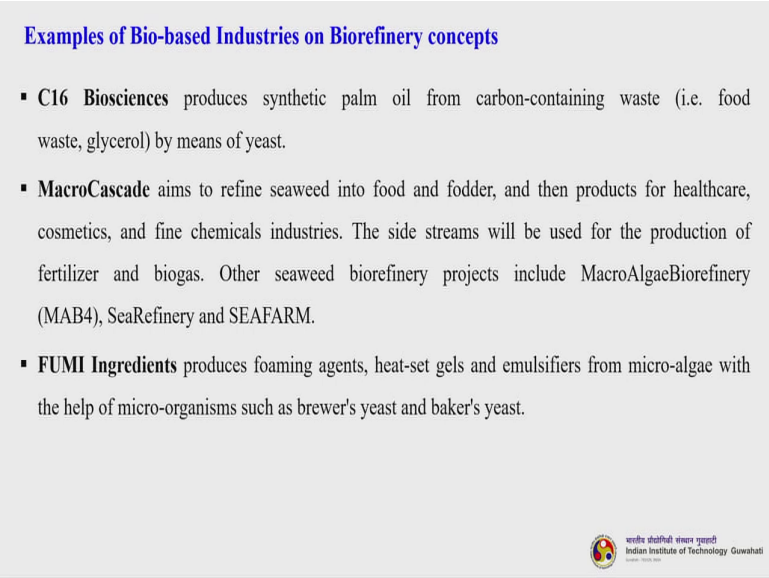

C16 Biosciences they produce synthetic palm oil from carbon containing waste. Then there is MacroCascade that aims to refine seaweed into food and fodder, and product for health care, cosmetics, fine chemical industries and they have processed other things also. FUMI Ingredients that produces foaming agents, heat set gels and emulsifiers from microalgae with the help of microorganisms such as yeast and brewer's yeast.

BIOCON, it is an Indian company. So they a processing the wood into various products. More precisely, their researchers are looking at transforming Lignin and cellulose into various products. Lignin based biorefineries are also there. Lignin for example can be transformed into phenolic components which can be used to make glue, plastics and agricultural products (crop protection). Cellulose can be transformed into clothes and packaging.

Now, in South Africa there is a company called Numbitrax LLC. They have bought a Bloom biorefinery system for producing bioethanol as well as additional high return offtake products from local and readily available resources such as prickly pear cactus plant basically. Then; BiteBack Insect that makes insect cooking oil, insect butter and all these things.

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Then there is a company called Circular Organics (it is a part of Kempen insect Valley) that grows black soldier fly larvae on waste from the agricultural and Food Industry. So Fruit and Vegetables surplus, remaining waste fruit juice and jam production (basically the solid waste). These larvae are used to produce protein, grease and chitin. So, the grease is usable in the pharmaceutical industries for cosmetics, surfactant for shower gel thereby replacing other vegetable oil such as palm oil or it can be used as fodder also.

So with this I complete my lecture today. So thank you very much. And in the next lecture we will start module 2. The module 2 is focused on biomass. So, we will be discussing the availability and abundance of biomass, photosynthesis, composition and energy potential, virgin Biomass production, agricultural, forestry waste and all these things. Their availability and potential.

So thank you very much once again, and if you have any query, please write to me at kmohanty@iitg.ac.in or you can also write to me in the Swayam portal. Thank you.