Biomass Conversion and Biorefinery
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Lecture 07
Basic Concepts and Types

Good morning students. This is module 3 and lecture 1. Under this module we will be discussing about the biorefineries. And in today's class we will discuss about basic concept. What is definition of biorefinery, how biorefinery functions, and what are the different types of biorefineries?

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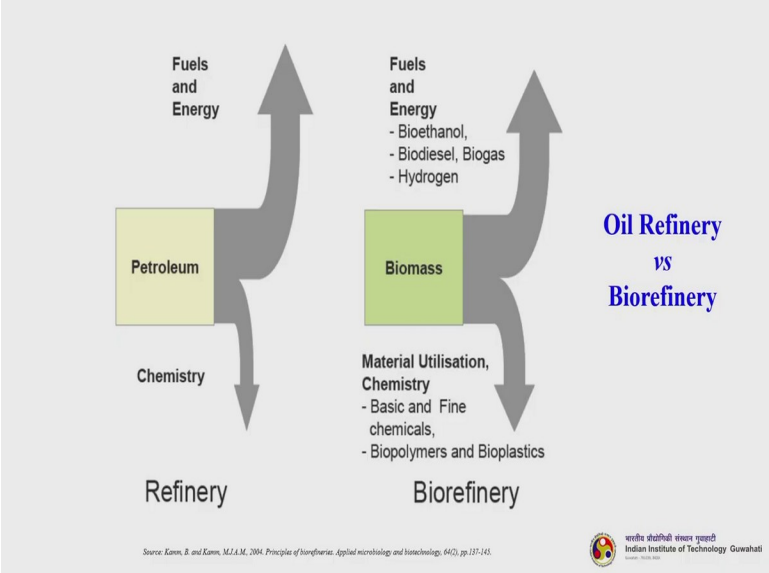

Let us start. Please have a close look at this particular slide. I have deliberately added (this slide) to make you understand the difference between Traditional oil refinery and biorefinery. So, this is the traditional oil refinery, in which petroleum or petro crude is being processed to fuels and energy and some platform Chemicals. The core is here; the petroleum in the core is the crude oil.

Here the core feedstock is the Biomass. So you will have so many different types of products from here. Fuels and energy so it can be bio-ethanol, biodiesel, biogas, hydrogen and all sorts of liquid and gaseous fuels and even some solid fuels also. Then there can be some material utilisation, like your basic and fine chemicals (which we call many times platform chemicals), then Polymers and plastics. So the basic difference between Traditional refinery and biorefineries is that, in biorefinery Biomass is the feed stock.

There are so many different types of biomasses that can be utilised. So the feedstock can be of n number of types. Not like in the petroleum refinery where only petro crude is being processed. And the processes are more or less similar in the sense of their principle, whether it is thermo chemical or sometimes bio-chemical also, and then we will have a number of different types of products.

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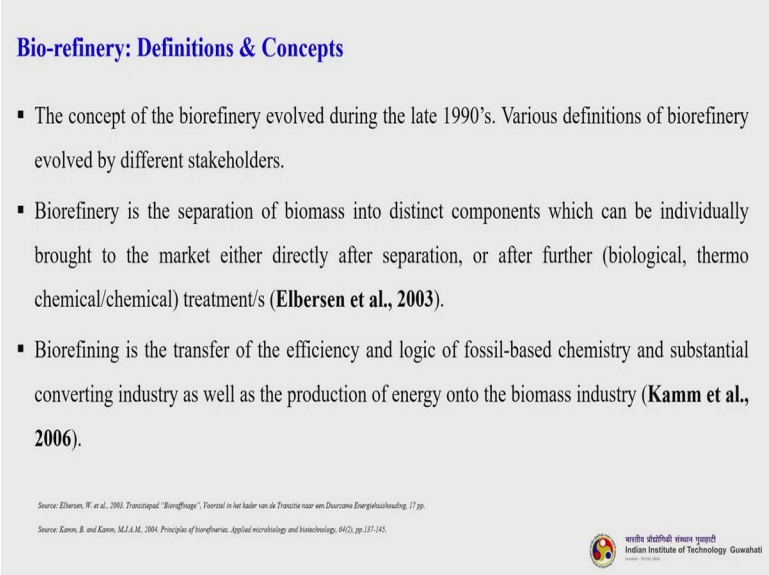

So the concept of the biorefinery evolved during the late 1990s. Various definitions of biorefinery evolved by different stakeholders. Biorefinery is the separation of biomass into distinct components which can be individually brought to the market either directly after separation or after further (biological, thermochemical or chemical) treatment/s. Bio-refining is the transfer of the efficiency and logic of fossil-based chemistry and substantial converting industry as well as the production of energy on to the Biomass industries. So, these are few; there are hundreds of such definitions provided by various stakeholders.

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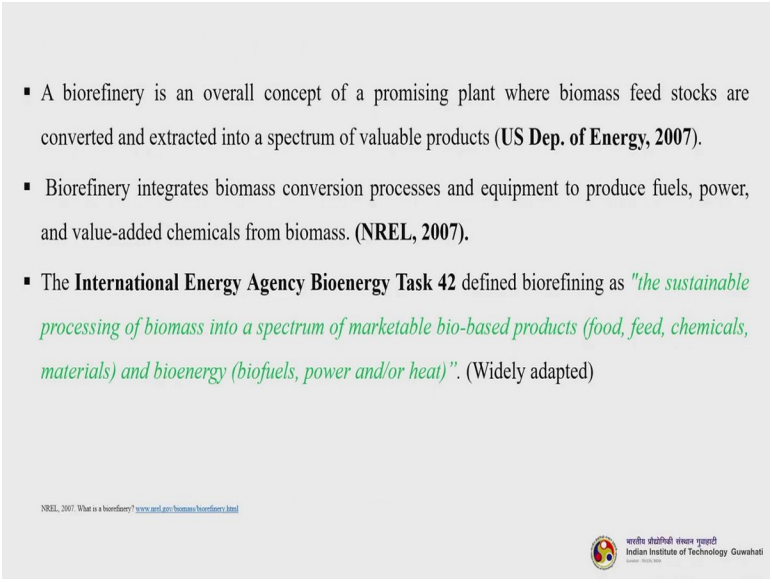

Biorefinery is an overall concept of a promising plant where Biomass feedstocks are converted and extracted into a spectrum of valuable products (this is what the US department of energy has defined). NREL says that, biorefinery integrates Biomass conversion processes and equipment to produce fuels, power and value-added chemical from Biomass. Then International Energy Agency's Bioenergy Task 42, they defined biorefining as the sustainable processing of biomass into a spectrum of marketable bio-based products (it can be food, feed, chemical materials) and bioenergy (biofuels, power and/or heat). And this is what is being widely accepted by the scientists.

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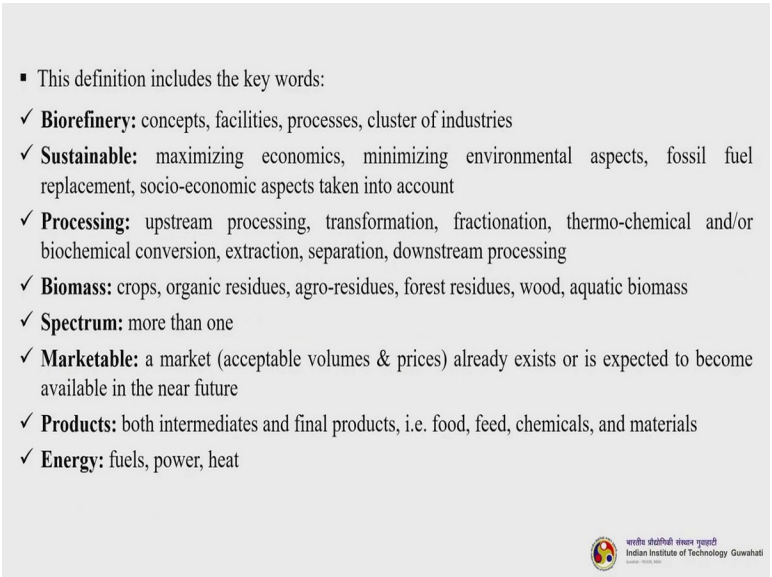

So, this particular definition, this NREL definition, includes the following keywords and we will try to understand what are those:

- Biorefinery: So here the concepts, facilities, processes and clusters of industries come into picture.
- When you talk about sustainable; that means maximizing the economics, minimising environmental aspects, fossil fuel replacement, socio economic aspects taken into account.
- Then processing: upstream processing, transformation, fractionation, thermochemical and/or biochemical conversion, extraction, separation and downstream processing.
- Then Biomass: what biomass means (with biorefining perspective). So, it can be crops, organic Residues, agro residues, forest residues, wood, aquatic Biomass (such as algae and all).
- Then spectrum, spectrum means more than one.
- Then marketable: A market (having an acceptable volume and prices) already exists or is expected to become available in the near future.
- Then products: both intermediate and final products, i.e., food, feed, chemicals and materials.
- Then energy: energy means fuels, power and heat.

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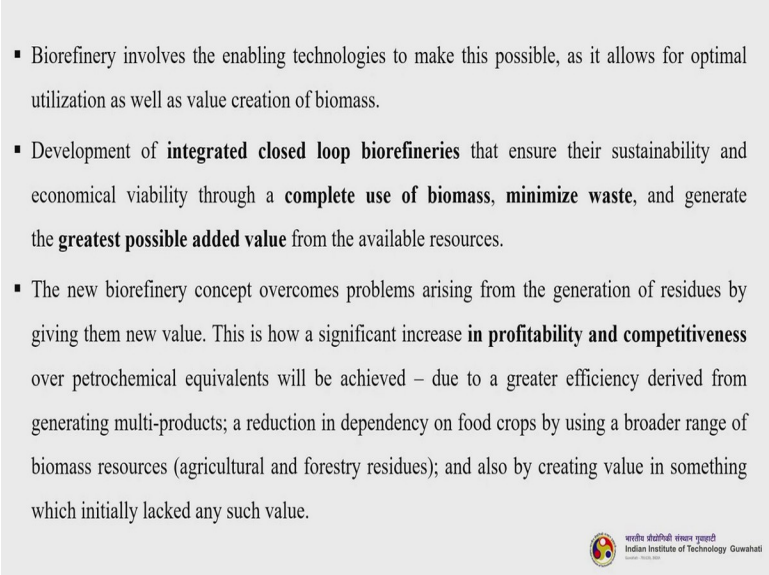

So, biorefinery involves the enabling Technologies to make this possible as it allows for optimal utilisation as well as value creation of biomass. Development of integrated closed loop biorefineries that ensure their sustainability and economical viability through a complete use of biomass, minimise waste and generate the greatest possible added value from the available resources. The new biorefinery concept overcomes problems arising from the generation of residues by giving them new value.

This is how a significant increase in profitability and competitiveness over petrochemical equivalents will be achieved - due to a greater efficiency derived from generating multiple products. So biorefinery always targets for multiple products because we have to understand that the feedstock is of low commercial value that we are going to utilise. Though its initial value will be low. However, due to the densification and transportation cost, the cost of the feed stock from procuring and to that of the plant will increase enormously basically.

Another thing I have already discussed and again I am telling you; feedstock sustainability is it always a big question because most of the feedstock are seasonal. Unless and until we standardize them for a particular biorefinery with multiple feedstocks, we cannot have a sustainable biorefinery. And to do that, we should aim for more number of value added products or co-products.

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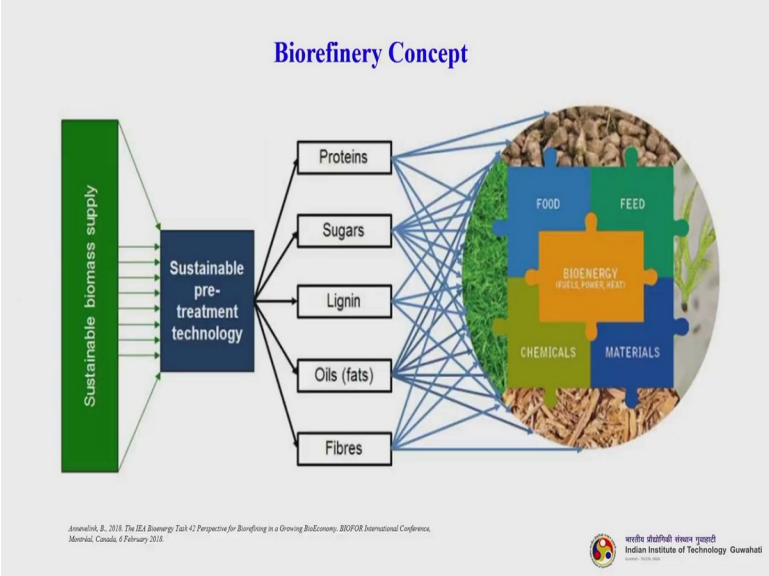

So, please have a look on this particular slide. Let us see what it means actually. It is a concept. Here you can see that sustainable biomass supply. This is what I was just mentioning; biomass supply should be sustainable. The inherent meaning of that; because they are seasonal, so we should look for different types of biomass basically or multiple feedstocks, so that their procurement will not face any problem throughout the year.

Then Sustainable Pre-treatment Technology. So pre-treatment technologies should be developed in such a way that they are, efficient in handling almost all the feedstock. Whatever maybe it? Some may be high lignin content; some may be less lignin content. How

the pretreatment technology is going to address these issues low lignin content or high lignin content, will depend upon what type of pretreatment technology is, being developed and adopted.

Then you can get for different platforms: protein, Sugars, lignin, oils and fats and fibres. And then you convert into various materials.

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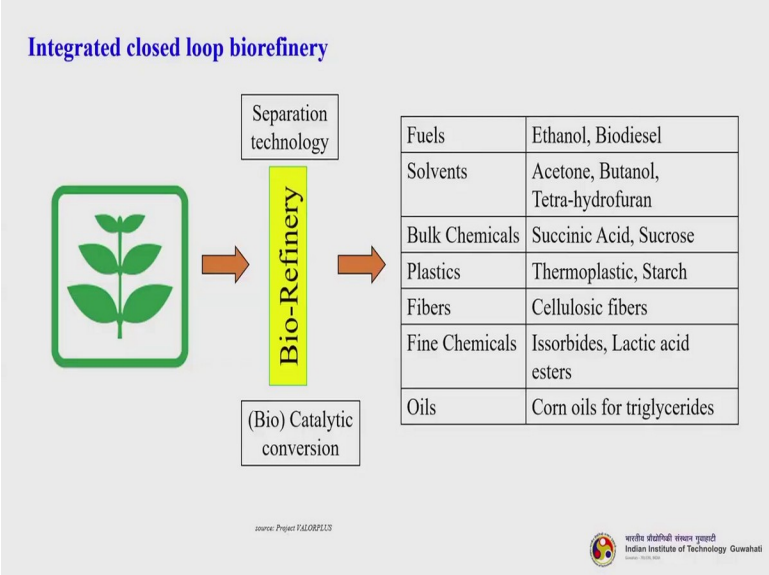

So separation technology is an integrated part of any refinery; whether it is a petrochemical refinery or a biorefinery. And based on my understanding, it cost almost about 40% (sometimes little higher than that of the entire product cost). So, you can understand that unless and until you have a very good and low-cost separation technology, our final end-product will be always very costly.

So, then you get so many different types of products. This already I have shown you long back also. So, we will just quickly glance through.

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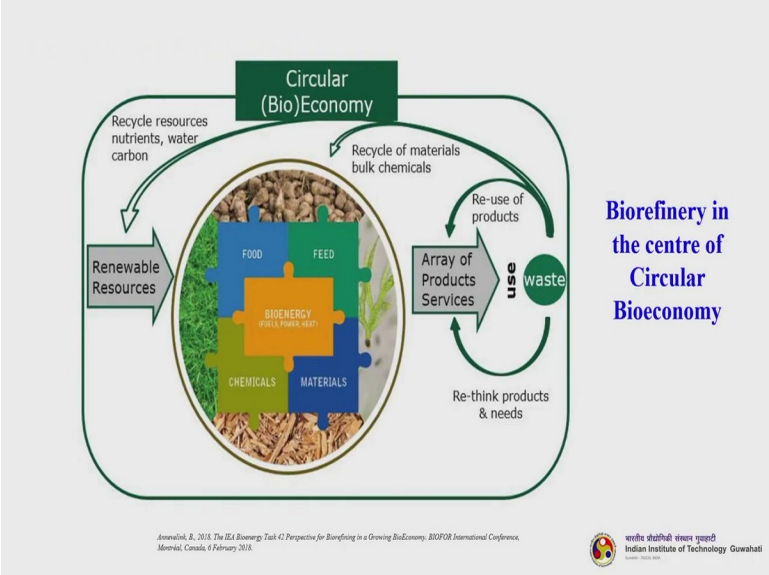

Then now there is so much of talk about circular bio economy. Meaning of circular bio economy is that whatever we are actually producing as a final product, once they are consumed, some waste is coming out of that. The by-products and the waste that is getting generated during the processing should be recycled and reused in such a way that it almost becomes a circular economy.

And also the economy of the rural people and other people who are engaged in these industries are also being taken care of. You can see this: recycle, resources, nutrients, water and carbon. Then renewable sources. This is the core of the circular bio economy, which is your biorefinery. Then you get array of different products, services; use them and you generate waste. And these wastes should also be recycled back.

I mean it should be processed into some valuable products. In one class I have given an example of the wastewater and how water and wastewater that is being used in the Refineries must be treated and recycled back. So, that we have to depend less on the freshwater because freshwater resources are also depleting year by year. So then you have to recycle materials bulk chemicals. So, it takes into account all these recycle and reuse of the materials basically.

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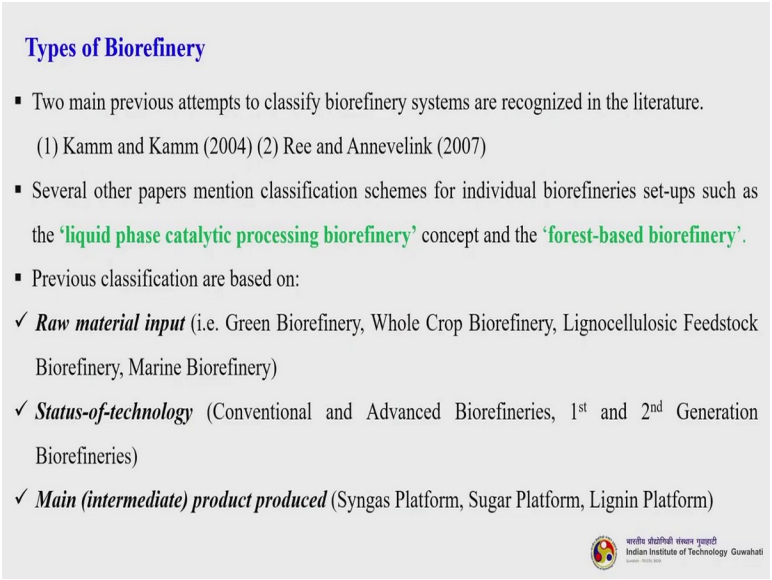

Let us now understand the different types of biorefinery. Two main previous attempts to classify biorefinery systems are recognised in the literature. This is by Kamm and Kamm and Ree and Annevelink. The corresponding citation I have given in some other slides; it will come actually in the subsequent slides. So, several other papers mention classification schemes for individual biorefinery set-ups such as the liquid phase catalytic processing biorefinery and the forest based biorefinery.

So, previous classifications are based on: Raw material input (either it can be a green refinery, it can be a whole crop biorefinery, it can be lignocellulosic feedstock biorefinery, it can be a Marine biorefinery); Status of technology (either it is conventional or advanced biorefinery, first and second generation biorefinery); then main (intermediate) products produced (Syngas platform, sugar platform, Lignin platform). So slowly we will see all these things.

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The major different biorefinery types are:

SN	Biorefinery types	Features
1	The conventional biorefinery	based on existing industries, such as the sugar and starch industry.
2	The whole crop biorefinery	uses raw materials, such as cereals or maize
3	The green biorefinery	uses nature-wet biomasses, such as green grass, alfalfa, clover or immature cereal
4	The two-platform concept biorefinery	includes the sugar and the syngas platforms
5	The lignocellulosic feedstock biorefinery	uses nature dry raw material, such as cellulose-containing biomass and wastes
6	The thermochemical biorefinery	based on a mix of several technologies
7	The marine biorefinery	based on marine biomass (micro and macro algae).
8	The liquid-phase catalytic processing biorefinery	based on the production of functionalized hydrocarbons from biomass-derived intermediates
9	The forest-based biorefinery	based on the full integration of biomass and other feedstocks (including energy), for simultaneous production of pulp, (paper) fibers, chemicals and energy.

So please have a look at this particular slide where you can see that there are different types of biorefineries listed. 9 different types and their features. So, the conventional biorefinery; based on the existing industries such as the sugar and starch industry. The whole crop biorefinery; it uses raw material such as cereals or maize. The green biorefinery; it uses nature-wet biomasses, such as green grass, alfalfa, clover or immature cereals. Then 2 platform concept biorefinery; this includes sugar and syngas platforms. Lignocellulosic feedstock biorefinery; uses nature dry raw material such as cellulose containing Biomass and wastes. Then thermochemical biorefinery; so this is based on a mix of several Technologies, it can be gasification, it can be pyrolysis. Then the Marine biorefinery; So that is based on the Marine biomass (basically micro and macroalgae). Then liquid phase catalytic processing biorefinery; this is based on the production of functionalized Hydrocarbons from biomass-derived intermediates. Then forest based biorefinery; based on the full integration of biomass and other feedstocks (including energy) for simultaneous production of pulp, paper, fibres, chemicals and energy. This is all about the different types.

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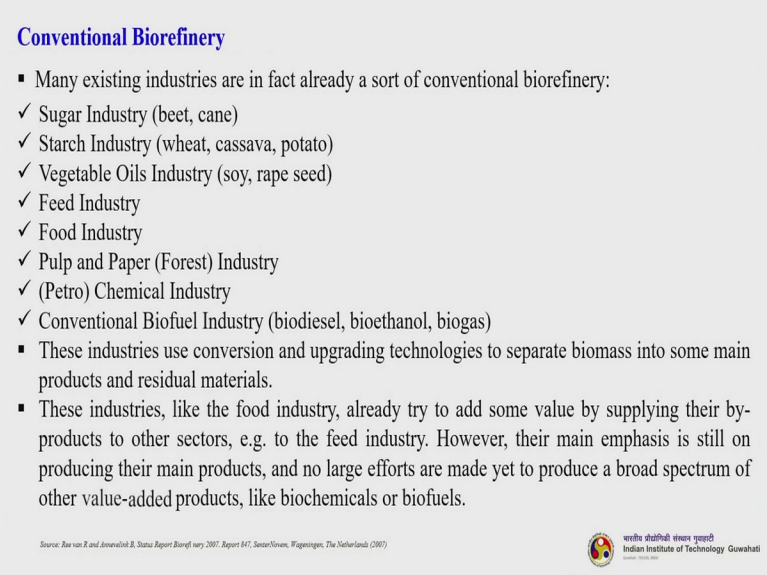

We will just the conventional biorefinery what it means actually. So, many existing industries are in fact already a sort of conventional biorefinery. So, either the sugar industry, starch industry, vegetable oil industry, feed industry, food industry, Pulp and Paper, chemical industry, conventional biofuel industries. Now these industries use conversion and upgrading Technologies to separate Biomass into some main products and their residual materials.

And these Industries like the food industry already try to add some value by supplying their by-products to other sectors. As for example, to the feed industry. However, their main emphasis is still on producing their main products and no large efforts are made yet to produce a broad spectrum of other value-added products like bio chemical or biofuels. That is not happening in a large scale.

So, most of the focus is always on the main product development. However, the focus should now be shifted to how you can generate the by-products and other wastes and convert them into value added products. So that biorefinery will become both sustainable and economical.

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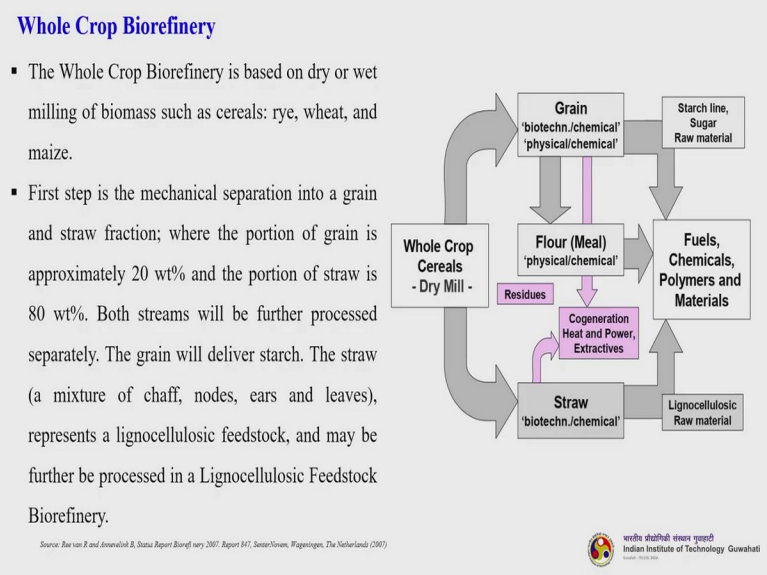

Please have a close look at this one. This is the whole crop biorefinery. In the whole crop biorefinery this is based on dry or wet milling of biomass such as cereals: whether it is rye, whether it is wheat, or whether it is maize. So what is being done in the first step is the mechanical separation into grain and straw fractions, so you get a grain fraction here, so you get a straw fraction here.

Now this grain and straw fractions will be converted. Approximately 20% is the grain fraction and the straw is almost 80%. So both streams will be further processed separately. The grain will deliver starch (so that is the starch platform). Then the straw (which is a mixture of chaff, nodes, ears and leaves) represent the lignocellulosic feedstocks and may be further processed in a lignocellulosic feedstock biorefinery.

So here, what we understand in the whole crop biorefinery is that, initially crop will be processed into starch platform and a lignocellulosic based platform. Now that lignocellulosic based, whatever we are getting generated, the straw basically, can be further processed in a lignocellulosic biorefinery to other value-added chemicals and products.

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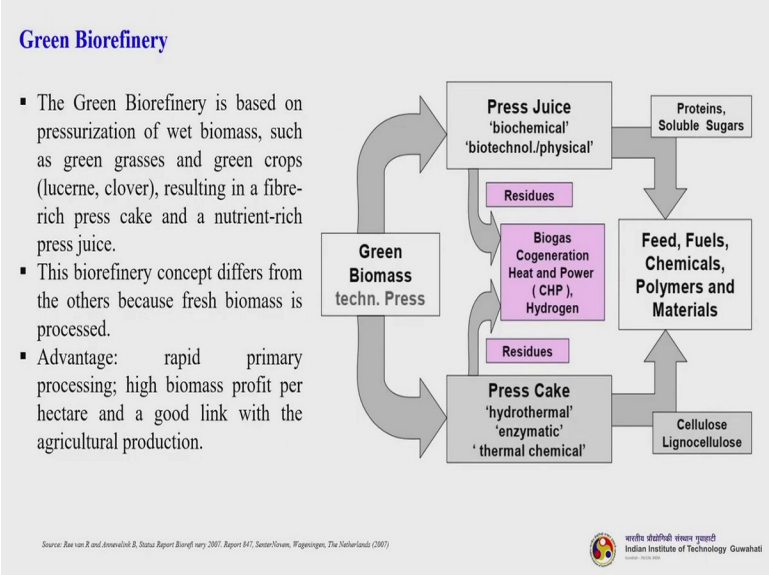

Next is Green biorefinery: Now the green biorefinery is based on the pressurization of wet biomass such as green grasses and green Crops resulting in a fibre rich press cake and nutrient rich press juice. The first initial step is that whatever the mechanical processing is being done, so we will get a juice which is almost 25% and the rest 70% - 75% is the press cake or the solid part. Now this biorefinery concept differs from others because fresh biomasses processed here.

Advantage is that: rapid primary processing, high biomass profit per hectare and a good link with the agricultural production. All agricultural production residues can be process here.

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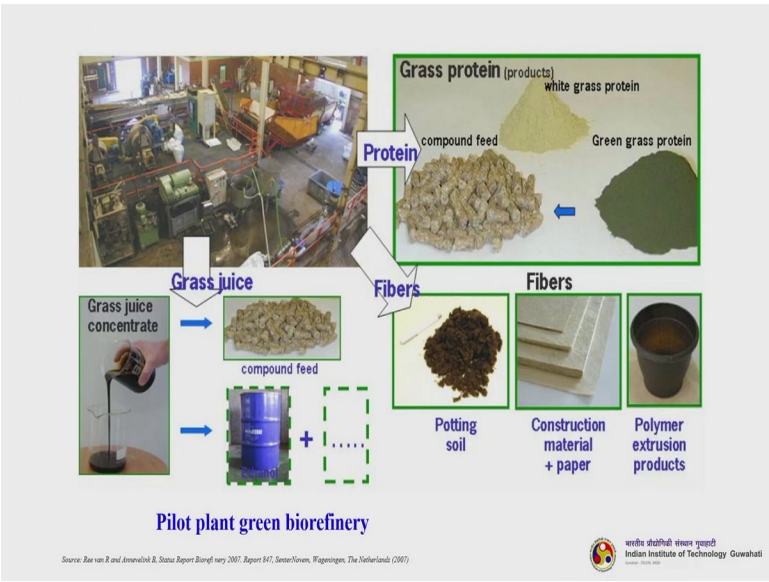

So this is an actual image of a pilot plant green biorefinery. So, you can see that the things are getting processed here. So we get a protein platform, we get a fibre platform, we have a grass

juice platform. The grass juice concentrate is here. Then this is a pilot plant biorefinery scheme actually. And here we can get so many products like construction materials, paper, polymer extrusions. There we get green grass protein and white grass protein. Now there are other so many things that is happening here.

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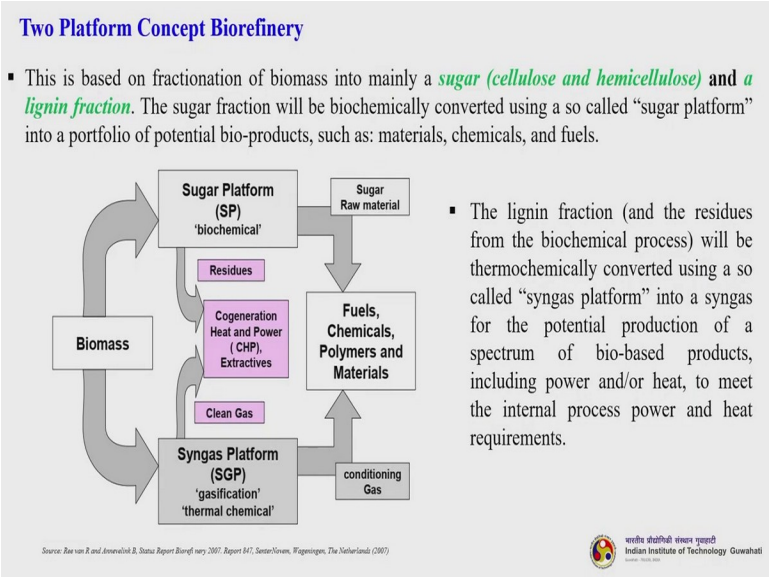

So let us understand the two platform concept biorefinery. This is based on fractionation of biomass into mainly a sugar (basically cellulose and hemicellulose, the C6 and C5 sugar) and a lignin fraction. Now, what is being done here is that, the Biomass, whatever it is coming, it is converted into two things (or fractionated). One, we get a sugar platform, where sugar is the raw material. Then it can be further processed to fuels, chemicals, polymer and raw material.

And then you have a platform which is the Lignin platform. That lignin platform can go to gasification (basically the thermal conversion) and you get a syngas here. Then we can have a co-generation (CHP basically) of heat and power; and we will also get fuels and chemicals and polymers from this platform.

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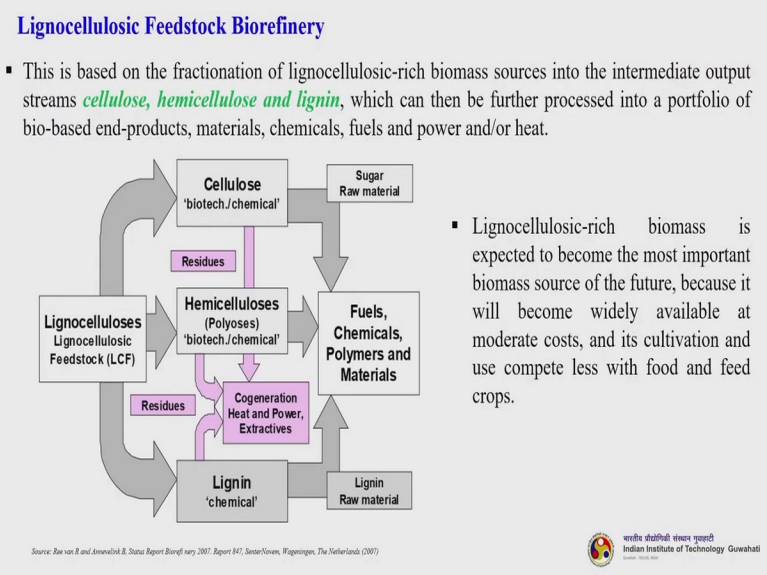

The next is lignocellulosic feedstock biorefinery. And this is most interesting because most of the biorefineries are now looking for lignocellulosic based feedstocks. This is based on the fractionation of lignocellulosic-rich biomass into the intermediate output streams cellulose, hemicellulose and lignin, which can then be further processed into a portfolio of bio-based end-products, materials, chemicals, fuels and/or heat.

Lignocellulosic-rich biomass is expected to become the most important biomass source of the future because it will become widely available at moderate costs, and its cultivation and use compete less with the food and feed crops. So that means, there is no food versus feed problem here. Please understand the difference between this and the earlier one. Here we are getting a sugar platform and then a syngas platform which is based on Lignin.

But Lignin can be converted into other things also. But in the lignocellulosic, we get cellulosic platform and we get a lignin platform here. Now, lignin is not producing syngas directly. It can produce whatever lignin can be used as a raw material. It is a very high value product or it can be used for the cogeneration, which was present in the earlier this one (Biorefinery) also. And there is a hemicellulose part also which needs to be taken care of also.

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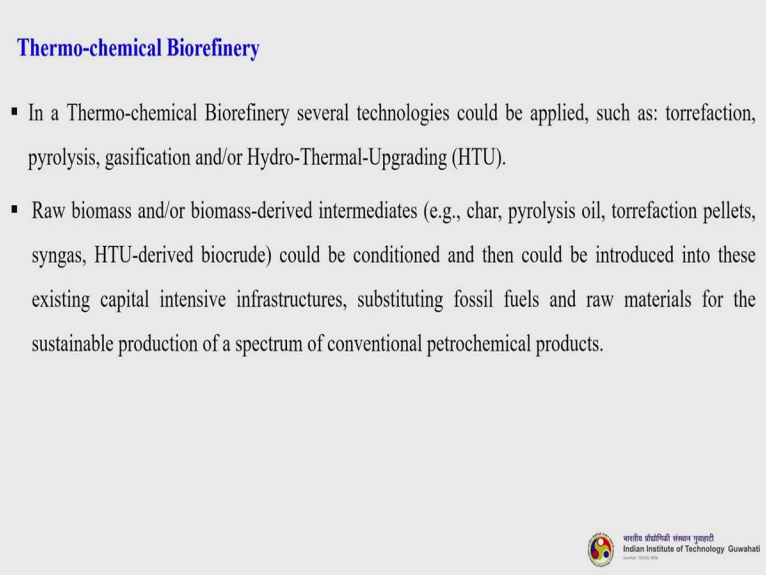

So then, thermochemical biorefinery. So in a thermochemical biorefinery, several technologies could be applied such as: torrefaction, pyrolysis, gasification and HTU or HTL (Hydrothermal upgrading or hydrothermal liquefaction). So, raw biomass and/or biomass-derived intermediates (as for example char, pyrolysis, oil, torrefaction pellets, syngas HTU-derived biocrude) could be conditioned and then could be introduced into these existing capital-intensive infrastructures, substituting fossil fuels and raw materials for the sustainable production of a spectrum of conventional petrochemical products.

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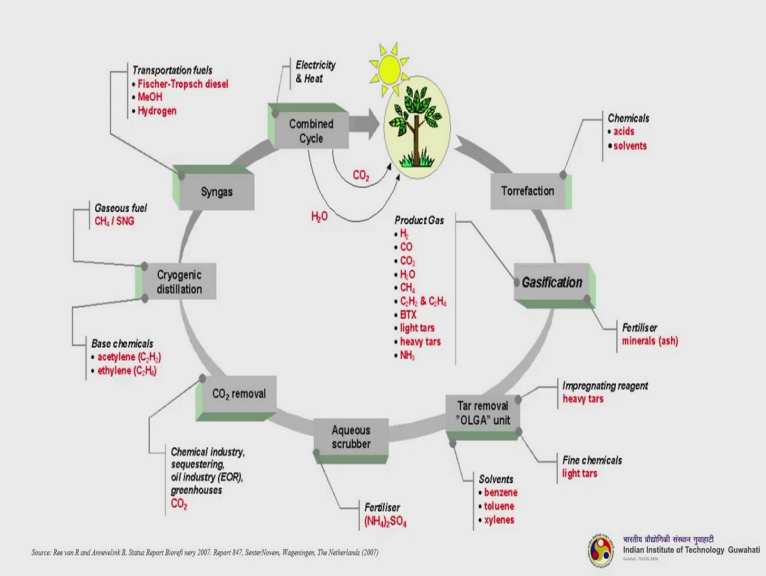

Now have a close look at this particular slide. You can understand how this particular refinery works; starting from the very source of the lignocellulosic materials, goes through torrefaction, gasification, you remove tar, go for a scrubbing, and whatever you scrubbed out (solid part) can be used as a fertilizer. Then you can remove carbon dioxide. You can

concentrate carbon dioxide also. Then you can go for cryogenic distillation where we can get acetylene and ethylene. Then we can have syngas, gaseous fuel and then the cycle goes on.

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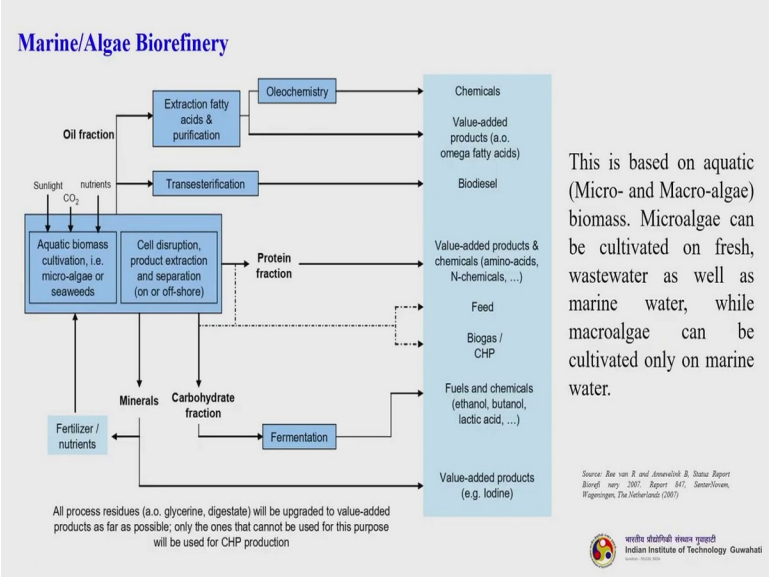

Then marine or algae biorefinery: That is more interesting now-a-days, because lot of work is being done on this particular aspect of the algal refineries. So this is based on aquatic, basically micro or macroalgae biomass. So microalgae can be cultivated on fresh wastewater as well as marine water while macroalgae can only be cultivated on marine water. Here what is happening actually; so you see this aquatic biomass that is getting cultivated here, it can be microalgae, seaweeds, macroalgae, whatever it is. Then you go for the initial cell disruption, product extraction (like remove the lipid content or oil whatever it is). Then, you can go for the oil fractionation. There basically you extract oil. Then it goes to chemicals, value-added products. You transesterify it to biodiesel. This is one of the most important aspect. Then there are so many things left, like minerals. It can go to fertilizers and nutrients. Whatever left out, the solid Biomass, I told you one in one of the class that it contains huge amount of carbohydrates. Of course, the exact amount will depend upon what species we're dealing with. Apart from that, there will be pigments, there will be vitamins, there will be some other important Chemicals also. The carbohydrate part can go to fermentation after hydrolysis. So you can get alcohol based fuels, either butanol or ethanol; and other value added products like pigments such as astaxanthin, beta-carotene; then you can also remove chlorophyll, it is a very important class of chemicals.

So, what not we are getting from a single component or single feedstock. Now the refinery should again be developed in such a way that you can a process different types of algae,

whether it is microalgae, macroalgae. There are hundreds and thousands of species. So the processes' technology should be developed in such a way that all sorts of different species can be converted in a single platform.

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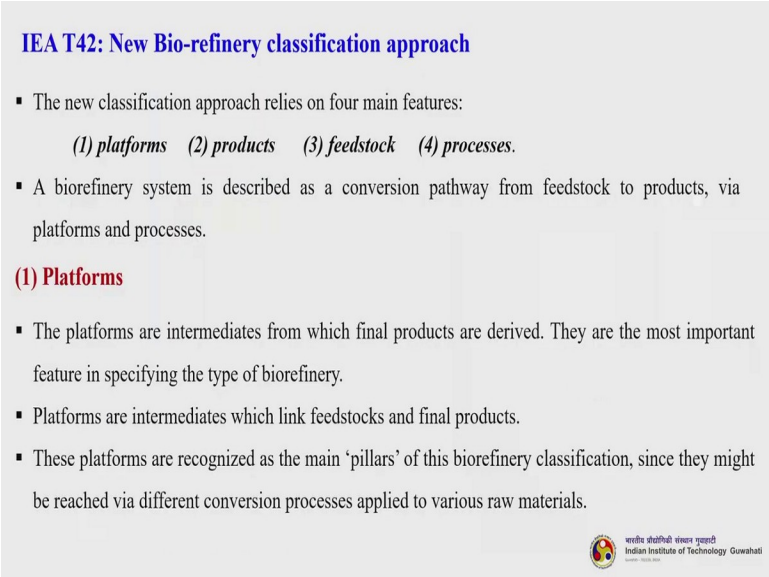

Let us now talk about, what the new biorefinery classification approach is, provided by the International Energy Agency (IEA). So, it says that the new classification relies on the four main features: first is the Platform; second is Products; third is Feedstock; fourth is Processes. So, based on these four things the biorefinery has been classified. A Biorefinery system is described as a conversion pathway from feedstock to Products via different platforms and processes.

Now first we will see the platforms. So, the platforms are intermediates from which final products are derived. They are the most important feature in specifying the type of biorefinery. Platforms are intermediates which link feedstocks and final products. These platforms are recognised as the main pillars of this biorefinery classification, since they might be reached via different conversion processes applied to various raw materials.

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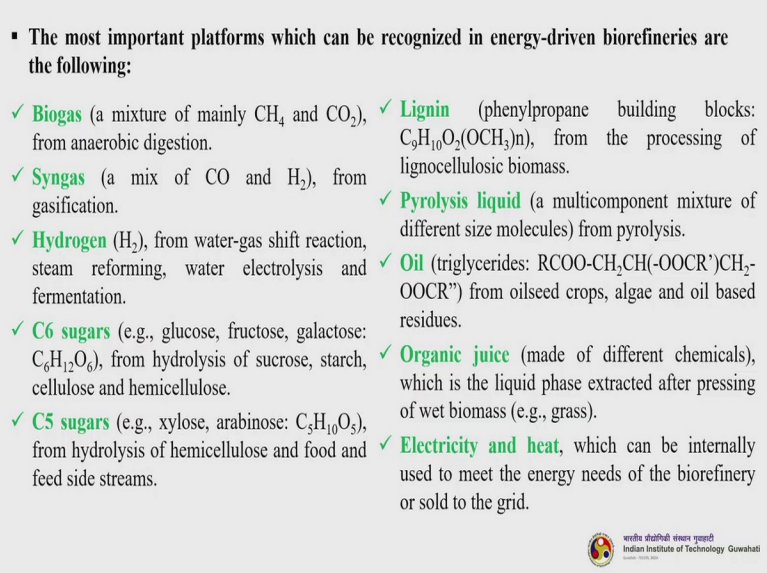

Let us see some of the platforms. The most important platforms which can be recognised in energy driven biorefineries are the following: Biogas (A mixture of mainly methane and carbon dioxide), it comes from anaerobic digestion; Syngas (a mixture of carbon monoxide and hydrogen), it comes from gasification; Hydrogen from water shift gas reaction, steam reforming, water electrolysis and fermentation (So, hydrogen come from various sources); C6 sugars (glucose, Fructose, galactose), from hydrolysis of sucrose, starch, cellulose and hemicellulose; C5 sugars (Xylose, arabinose etc.), from hydrolysis of hemicellulose and food and feed side streams; Lignin (phenylpropane building blocks), from the processing of lignocellulosic biomass; pyrolysis liquid or we call it pyrolytic liquid people call it bio oil also (So it is multi-component mixture of different size molecules), it comes from pyrolysis; Then oil (basically triglycerides which to convert to your biodiesel), comes from the oilseed crops, Algae and oil-based residues; then organic juice (made of different chemicals), which is the liquid phase extracted after pressing of wet biomasses (for example grass); Then the final one is electricity and heat, which can be internally used to meet the energy needs of the biorefinery or sold to the grid depending upon how much you are generating basically.

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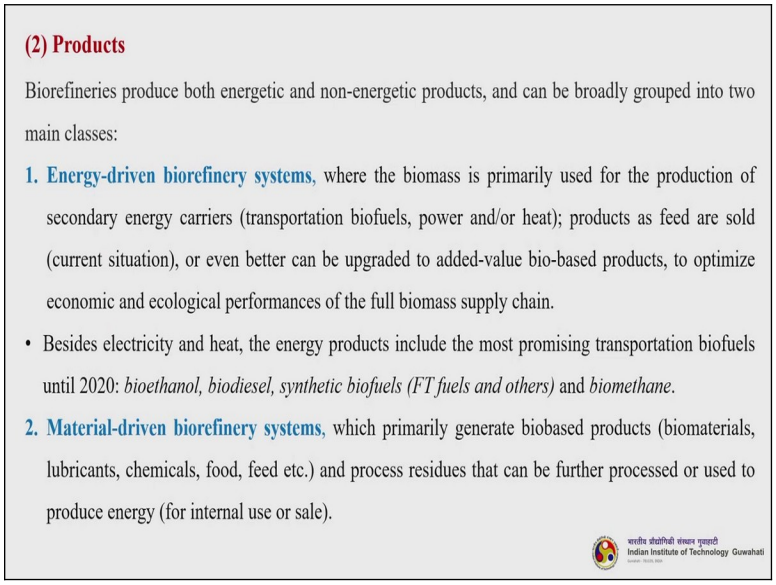

So the next is products. So biorefineries produce both energetic and non-energetic products and can be broadly grouped into two main classes: first is energy driven biorefinery system and the second is material driven biorefinery system.

So in energy driven biorefinery system, biomass is primarily used for the production of secondary energy carriers. So, secondary energy carriers are basically transportation fuels, power and/or heat. The products as feed are sold and even better can be upgraded to added-value bio-based products, to optimise economic and ecological performance of the full biomass supply chain. Besides electricity and heat, the energy products include the most promising transportation biofuels until 2020: bio-ethanol, biodiesel, synthetic biofuels (FT fuels or Fischer–Tropsch fuels and others) and maybe biomethane.

And in the material driven biorefinery systems, which primarily generate bio-based products (like biomaterial, lubricants, Chemicals, food and feed) and process residues that can be further processed and used to produce energy (It can be for internal use or for the outside sale also).

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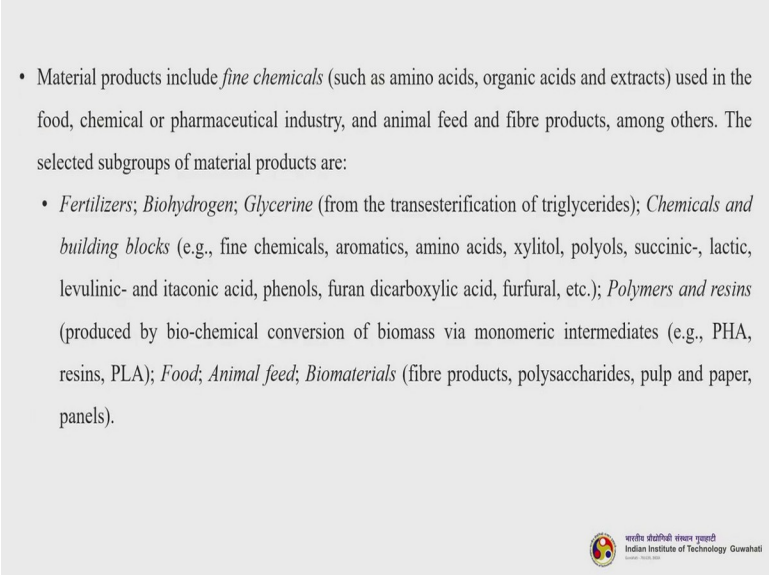

So, material products include fine Chemicals (such as amino acids, organic acids and extracts) used in the food, chemical, pharmaceutical industry and animal feed and fibre products among others. The selected subgroups of material products are: fertilizers; bio-hydrogen, glycerine (it can be from transesterification of triglycerides basically); Chemicals and building blocks (refer to the corresponding slide for examples); then we can have Polymers and resins; we have food; animal feed; and bio materials. So, different types of materials-based platform.

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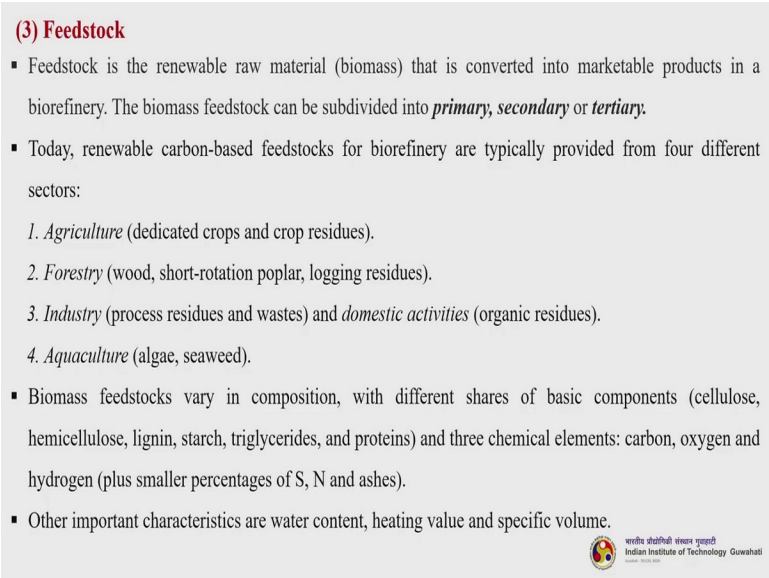

So the next is feedstock. Feedstock is the renewable raw material that is converted into marketable products in a biorefinery. The Biomass feedstock can be subdivided into primary, secondary or tertiary. Today renewable carbon-based feedstocks for biorefinery are typically provided from four different sectors: (1) Agriculture (which is dedicated crops and crop

residues); (2) Forestry (that is wood, short rotation poplar, logging residues); (3) Industry (process residues and waste) and Domestic activities; and (4) Aquaculture (which is algae and seaweed).

Now Biomass feedstocks, vary composition with different shares of basic components (cellulose, hemicellulose, lignin, starch, triglycerides and proteins) and three chemical elements: carbon, oxygen and hydrogen (plus smaller percentage of sulphur, nitrogen and ashes). Other important characteristics are the water content, heating value, specific volume. This is the most important thing here: different shares of basic components. This is what doesn't happen in the petroleum refineries. The crude which we process in petroleum refineries, they are almost similar in composition. Of course they vary slightly depending on from where it is; is it Indian crude, gulf crude (from where it is coming depending upon that it varies). But not so much like Biomass. So that is why, biorefinery is extremely challenging.

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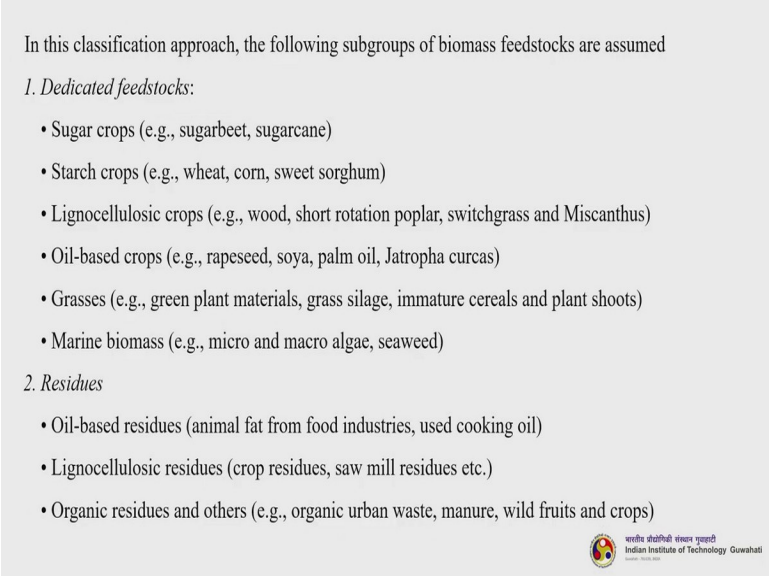

So, in this classification approach, the following subgroups of biomass feedstocks are assumed: First one is dedicated feedstock: it can be sugar crop, starch crops, lignocellulosic crops, oil-based crops, grasses, marine biomass (like algae); The seconds is residues: oil-based residues (It can be animal fat from the food processing industries or used cooking oil - many times it is called waste cooking oil), then lignocellulosic residue, organic residue and others.

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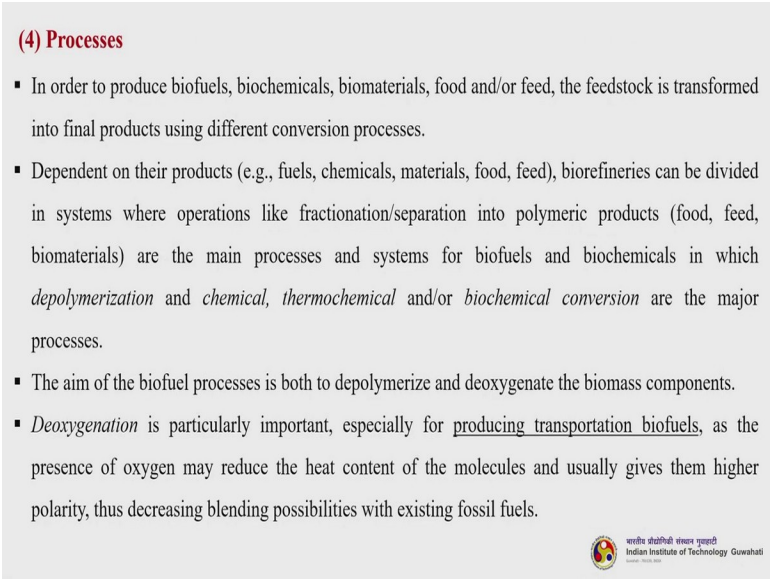

Then let us understand the processes. So, in order to produce biofuels, biochemicals, biomaterials, food and/or feed, the feedstock is transformed into final products using different conversion processes. Dependent on their products biorefineries can be divided in systems where operations like fractionation/separation into polymeric products are the main processes and systems for biofuels and biochemicals in which depolymerisation and chemical, thermochemical and/or biochemical conversion are the major processes.

Apart from this there is an important process, which is called deoxygenation. Now deoxygenation is important especially for those processes which are producing transportation biofuels because the presence of oxygen may reduce the heat content of the molecules and usually gives them higher polarity, thus decreasing blending possibilities with the existing fossil fuels. So for the transportation sector you need to deoxygenate the liquid fuel.

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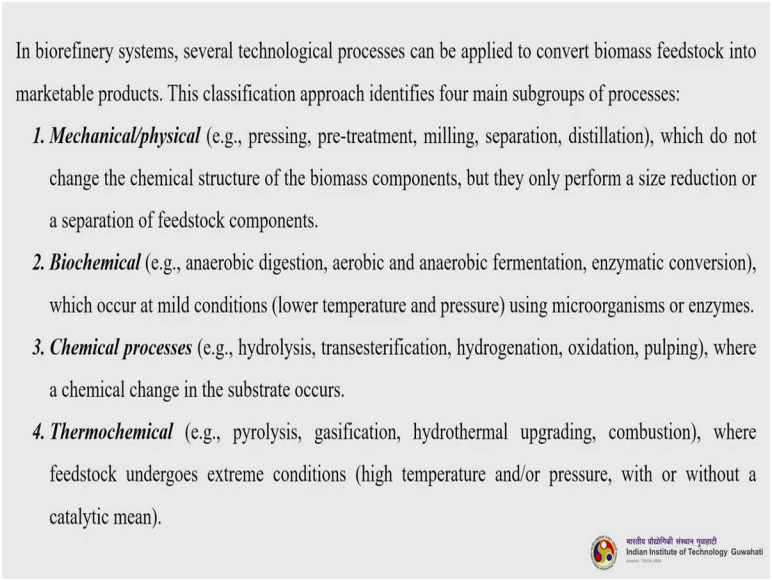

So in the biorefinery systems, several technological processes can be applied to convert Biomass feedstock into marketable products. This classification approach identifies main subgroups of processes such as: mechanical and physical, biochemical, chemical processes and thermochemical. This is what we have already discussed in some of our slides of this particular lecture.

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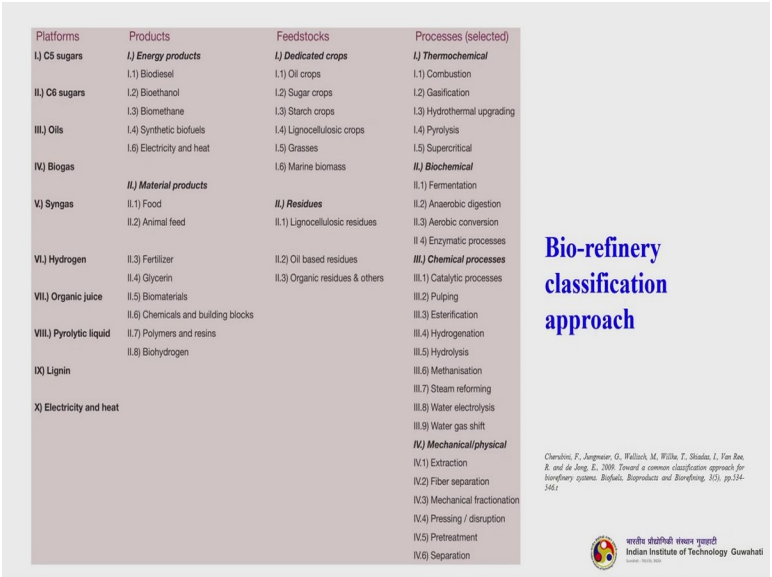

So, you can quickly have a glance through all the things. So basically, again in a single slide you can see the biorefinery classification based on platforms, products, feedstocks and processes. Now you can see there are n number of processes. All these processes are not mandatory to be present in all biorefineries; it is not so. What are the components (processes), this will basically depend upon what is your feedstock, what products you want and what are the platforms you are going to adapt.

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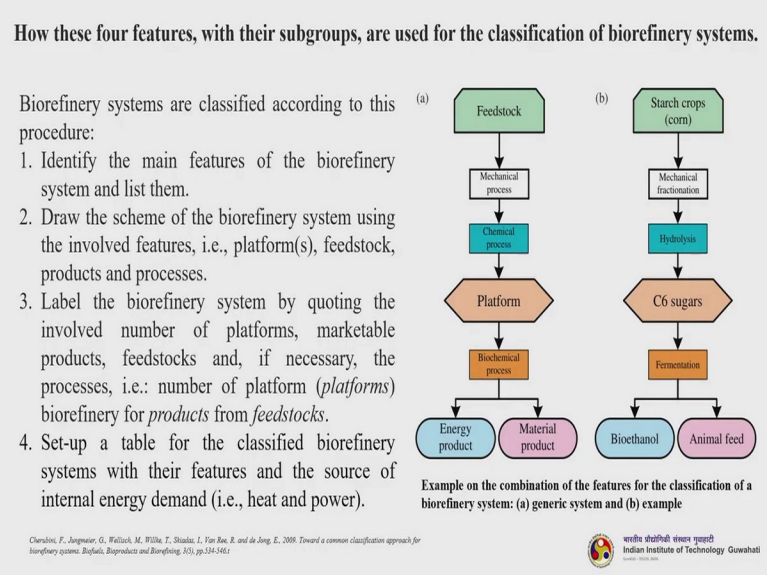

So how these 4 features with their subgroups are used for classification of biorefinery system. This is one classical example, just have a look at this particular image. So, this is one particular stream we can say that. It starts from feedstock, it goes for mechanical processing, then chemical processing, platform, then biochemical processes and then we get either energy or material products.

And if I take an example of corn, please have a look at (b), the starch crop. Corn is the feedstock there. Then I process it, mechanically process it, basically the pre-treatment part, then I hydrolyse it. What I will get? I will get in this platform; I will get C6 sugars. So, it is now a sugar-based platform. The platform becomes C6 sugar platform. Then it goes to the biochemical processing. Here the biochemical processing is fermentation and we get two or more than two products. Bio-ethanol the most important product and then whatever other things, for example, I have seen animal feed; there can be other products also.

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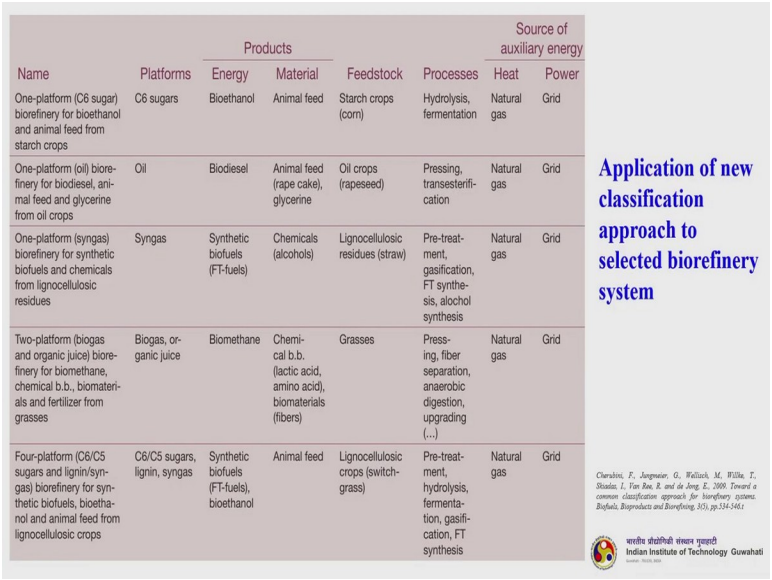

So, this is the application of new classification approach to selected biorefinery system. This is based on the product. So, the name, one platform C6 sugars, one platform biorefinery for biodiesel (oil based), syngas based, biogas and organic juice based, C6/C5 both and Lignin/syngas. Please have a look later on.

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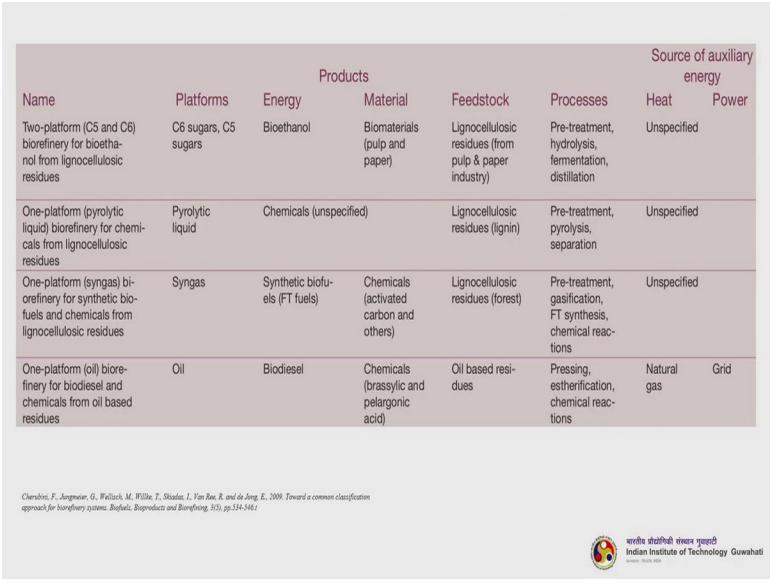

So, we continue with that actually, so again coming to different platforms here. So, this is a 2-platform system (C5/C6 sugars both it is processing). Then again one-platform based on the pyrolytic liquid. And then oil based platform and we get different types of products and the source of other energy like heat and power whether it can be possible or not. Whether it can be integrated into grid or not.

So, this is based on products. I again leave it to you, please go through it later on when you actually go through these slides. So, you can see what are the different types of platforms that we're using, basically sugar based. And then what are the energy output we are getting whether it is alcohol based liquid fuel or it is electricity, heat, or it is the gaseous like bio-methane.

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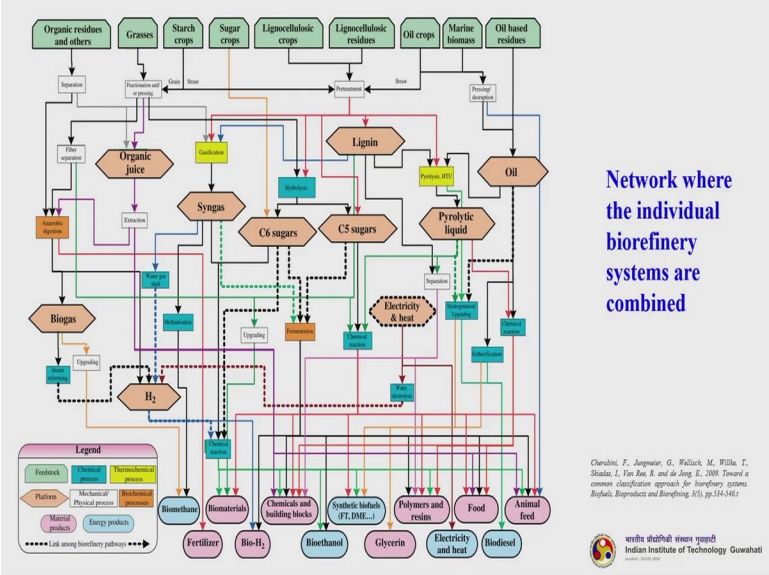

So, this is a classical example, this looks very complicated, but it is not so complicated. We can try to understand and follow actually what is actually happening. This is a network where the individual biorefinery systems are combined. So, it is a biogas platform, we are getting organic juice platform, syngas, hydrogen, we have C5 sugars, C6 sugars, lignin, we have pyrolytic liquid and oil-based platform.

So, all these have been integrated. How they are integrated? This particular slide is making you clear and make you understand. Please have a look, what are the products we are getting; n number of products: biomethane, biomaterials, fertilizer, biohydrogen, chemicals, ethanol, glycerine, Polymers and resins, food, feed, electricity and heat and biodiesel. This is how the different types of materials, all the top, the green ones, they are basically the feedstock. So, feedstock can be on organic residues here, grasses, starch crops, sugar crops, lignocellulosic crops, then lignocellulosic residues, then oil crops, Marine Biomass, oil-based residues and what not. Everything has been put and they have been integrated. So, it looks complicated because of the processes here, but you can understand in a nutshell that all these different types of feedstocks can be processed in an integrated biorefinery approach where we target basically for not only biofuels or bioenergy but also for multiple value added end products.

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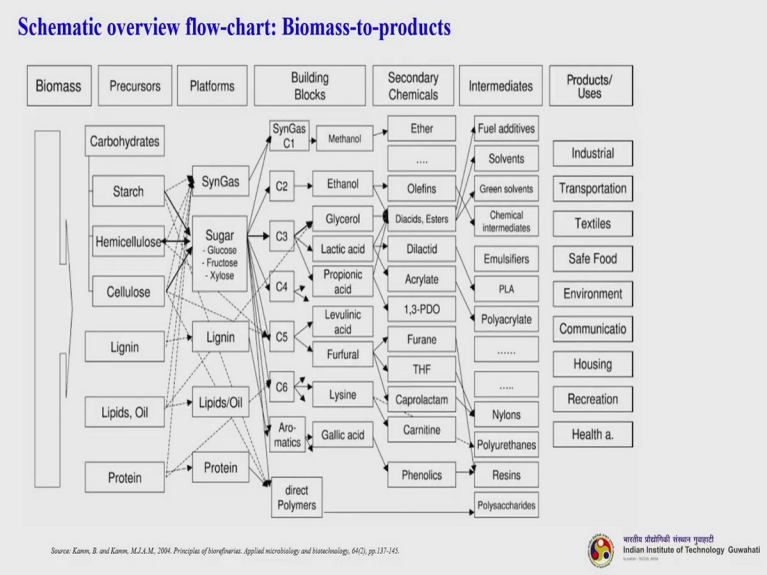

This is another example a little more simplified based on the biomass here and their precursors. So, the Biomass and their precursors; carbohydrates, starch, hemicellulose, cellulose, Lignin, lipid and protein which are extracted from the Biomass depending upon what type of biomass you are using; and is the platform syngas, sugar, lignin, lipid.

And this is arranged in a little simpler way than the earliest slide. The flow is little easy to understand here. So, you can see how they are integrated here. That means, one particular process or feedstock is being used by different platforms as well as it is being resulted into different end products which are again being integrated with each other to give some end-product of high commercial value.

I think with this I will stop today's lecture. So, if you have any questions please feel free to write to me kmohanty@iitg.ac.in or do post your queries in the Swayam portal. And in the next class the module 2 of the biorefinery module we will be discussing about the different feedstocks, their properties and integrated biorefinery concept. Thank you very much.