FOOD SCIENCE AND TECHNOLOGY

Lecture56

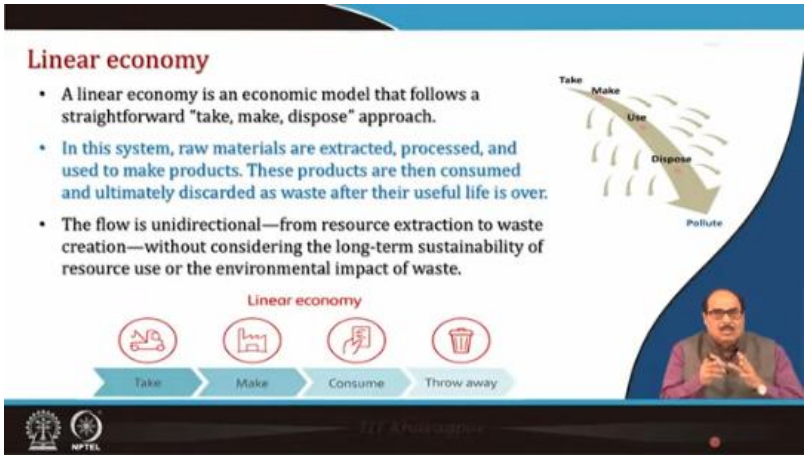
Lecture 56: Concept of Circular Economy

Hello everyone, Namaste. Now we are entering the twelfth module, which is the last module of this course, and the next five classes of this module shall be devoted to circular economy in the food industry.

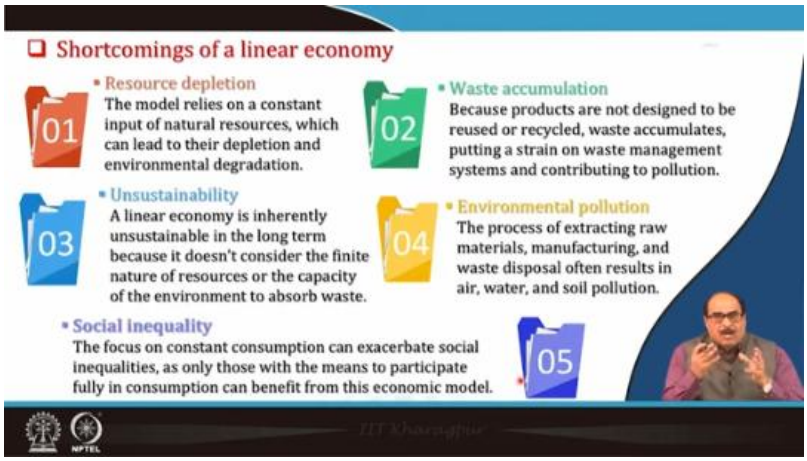
So, in this class today, we will study the concept of circular economy, that is, Lecture 56 overall, and Lecture 1 of this module is devoted to the concept of circular economy.

Here, we will discuss and study what the linear economy means and what the circular economy means, and also, we will compare both economies and the advantages of the circular economy. Then, we will also talk about the 2030 Agenda for Sustainable Development Goals, carbon neutrality, and green technology. Circular economy through

life cycle assessment and the various life cycle models, particularly those related to food products or the food processing industry, will be discussed in this.

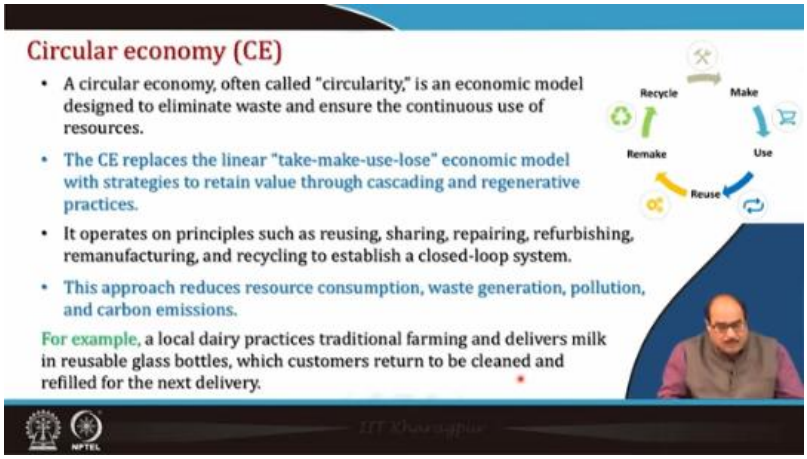


So, let us see what a linear economy means. A linear economy is an economic model that follows a straightforward approach, which is take, make, and dispose. Take, make, use, dispose—that is the linear economy. The raw materials of this system are extracted, processed and used to make products, and these products are then consumed and ultimately discarded as waste after their useful life is over. And the flow is unidirectional, as you can see here in this picture, which is from resource extraction to waste creation. Without considering the long-term sustainability of resource use or the environmental impact of the waste material, it is not considered. Here it is straightforward that if you take the material, make the product, consume it and throw away whatever is not used or whatever is left over. So, that is the linear economy.

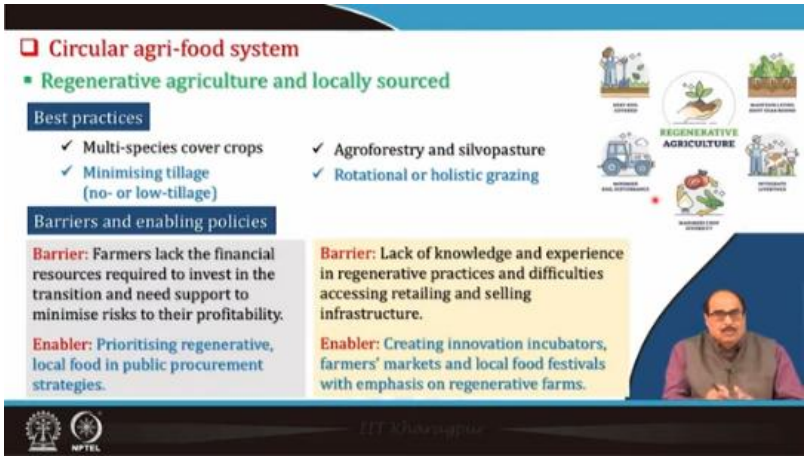


So, obviously, there have been some shortcomings of a linear economy, and if you say the 5 major shortcomings of the linear economy, I have narrated them here briefly. So, number

1 is the resource depletion. Means the model relies on the constant input of natural resources, which can lead to their depletion and environmental degradation. So, that is the major shortcoming of a linear economic model. Then the second shortcoming you can say is the waste accumulation. Because the products are not designed to be reused or recycled, waste accumulates. And it puts a strain on the waste management system and, therefore, contributes to pollution. Then there is unsustainability. A linear economy is inherently unsustainable in the long term because it does not consider the finite nature of resources or the capacity of the environment to absorb waste. So, another major shortcoming of the linear economy is environmental pollution. The process of extracting raw materials, manufacturing, and waste disposal often results in air, water, and soil pollution, etcetera. And therefore, finally, one major shortcoming of the linear economy is social inequality. The focus on constant consumption can exacerbate social inequality, as only those with the means to participate fully in consumption can benefit from this economic model. So, these shortcomings of the linear economy are addressed in the circular economy.



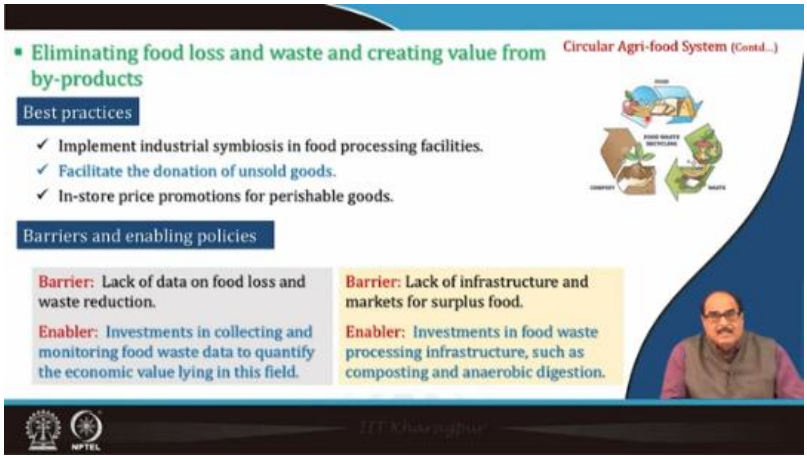
So, a circular economy, which is often called circularity, is an economic model designed to eliminate waste and ensure the continuous use of resources. The circular economy replaces the linear 'take, make, use, lose' economic model with strategies to retain value through cascading and regenerative practices. It operates on principles such as reusing, sharing, repairing, refurbishing, remanufacturing, and recycling to establish a closed-loop system. And this approach reduces resource consumption, waste generation, pollution, and carbon emissions. For example, take a local dairy. It practices traditional farming and delivers milk in reusable glass bottles. So, here, this dairy in the circular economy—what is that? It develops some sort of model and collection systems, it collects the bottles from the consumer end, and these bottles are cleaned, brought to the dairy, cleaned in the dairy, and then refilled for the next delivery. So, this becomes one sort of circular economy.



So, if you see, what are the various circular agri-food systems? If we look at how. So, number one comes the regenerative agriculture and locally sourced materials, etcetera. So, here, for regenerative agriculture, the best practices may be multispecies cover crops, agroforestry, and silvopasture. minimising tillage—there is no or low tillage, or rotational or holistic grazing. Like here, that is, in regenerative agriculture, you can see in the picture. It may be maintained living both year-round or integrate livestock, maximise crop delivery, minimise soil disturbance, keep soil covered, etc. So that you can get a region that has benefits, etc. However, this system may have certain barriers, and these barriers are to be taken care of by following certain enabling practices. For example, one barrier may be that farmer lack the financial resources required to invest in the transition and need support to minimise risk and improve their profitability. So, in this enabler practice, the priority should be prioritising regenerative. local food in a public procurement strategy. So that farmers can benefit, they can get financial help, etc. Then there may be another you can say technological barrier, etc., lack of knowledge and experience in regenerative practices, and difficulties accessing retailing and selling infrastructure. So, how can one enable? This barrier is creating innovation incubators. Even farmers markets and local food festivals with an emphasis on regenerative farms. So, this is one system you can say—regenerative agriculture and a locally sourced system.

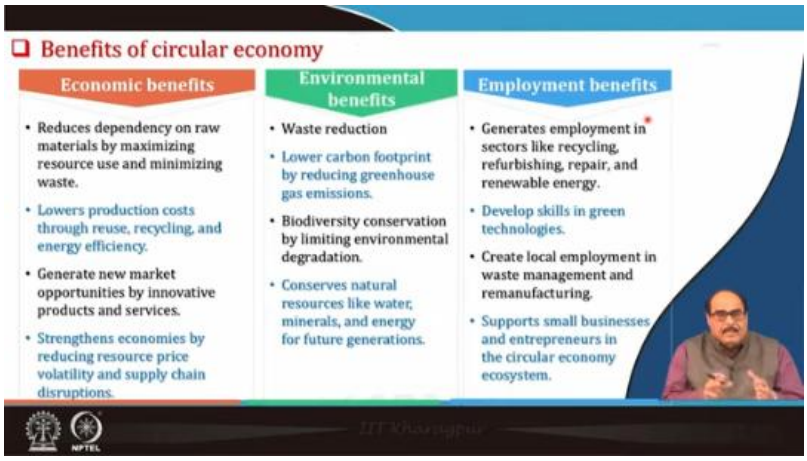
Then, another circular agri-food system may be that low-impact diets and packaging designed for circularity, and here, the best practice in this system may be producers shifting away from intensive farming practices and resource- and land-intensive biological products toward smaller-scale production and other activities which result in benefits. Another best practice may be prioritising the production and processing of food with lower inputs.

Retailers can use consumer design to shift consumer choices toward lower-impact, healthier diets, and so on. So, in this system, barriers and enabling policies may be like one barrier—reluctance to change diets and low consumer knowledge of food impacts. So, here's how they can be enabled: run consumer awareness campaigns. Then, another barrier may be the price competitiveness of low-impact foods. So, these can be enabled by price regulation measures. For example, tax breaks and/or subsidised prices for low-impact foods, etc. In this way, low-impact diets and packaging design for this system can be advanced in every food system.



Then another system may be eliminating food loss and waste, and creating value from byproducts. In this system, the best practices include implementing industrial symbiosis in food processing facilities, facilitating the donation of unsold goods, and in-store practice promotion for sustainable goods. So, here also the barriers and enabling policies may include the lack of data on food loss and waste resources, waste reduction, and this can be enabled by investments in collecting and monitoring food waste data to quantify the economic value in this field.

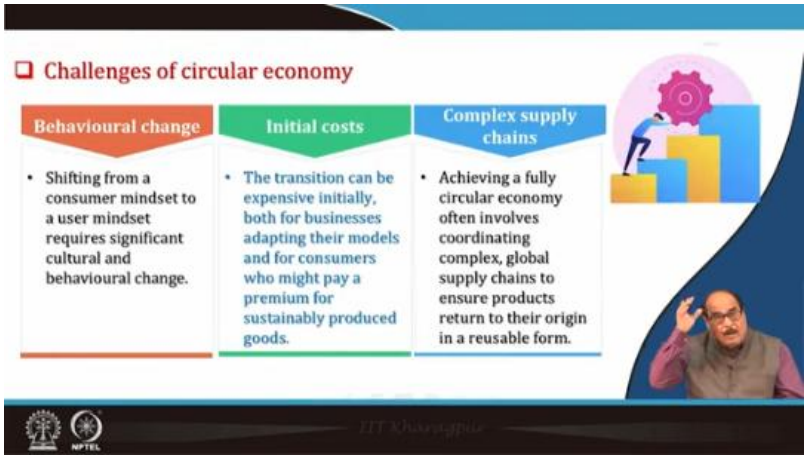
Another barrier in this system may be the lack of infrastructure and market for surplus foods. So, what can be done in this way? Investments in food waste processing infrastructure, such as composting and anaerobic digestion, etcetera, should be encouraged to sustain this system.



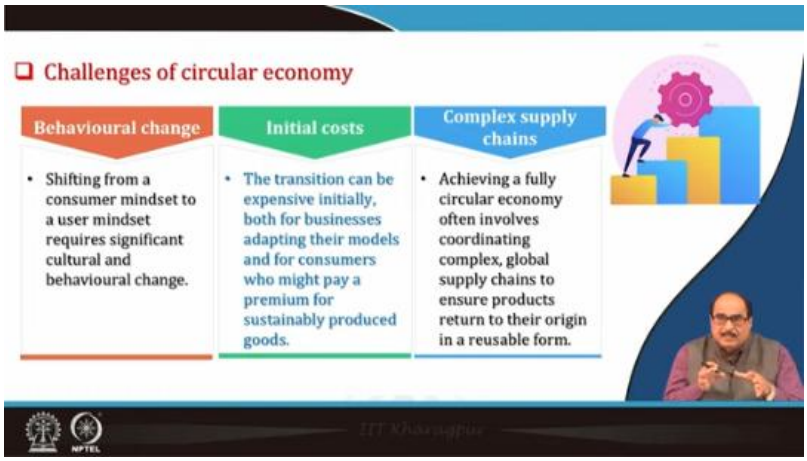
Then, let us briefly talk about the benefits of the circular economy. Obviously, it has three types of benefits: economic benefits, environmental benefits, as well as employment benefits. The employment benefit is the major benefit you can say in the circular economy. So, the economic benefits include reduced dependency on raw materials by maximising resource use and minimising waste. It lowers production costs through reuse, recycling, and energy efficiency. The circular economy generates new market opportunities through innovative products and systems, and it strengthens the economy by reducing resource price volatility and supply chain disruptions. The environmental benefits we get through the circular economy include waste reduction, a lower carbon footprint by reducing greenhouse gas emissions, biodiversity conservation by limiting environmental degradation, and conservation of natural resources like water, minerals, and energy for future generations. And the employment benefit is that it generates employment in sectors like recycling, refurbishing, repair, and renewable energy. For example, suppose you are making a system for the collection of used packaging material or other things. So, you need manpower to collect this from the resources. So, it generates employment. It develops skills in green technologies, creates local employment in waste management and manufacturing. It supports small businesses and entrepreneurs in the circular economy ecosystem.

However, like every system, there are certain challenges in the circular economy as well. These challenges include behavioural challenges like shifting from a consumer mindset to a user mindset, requiring significant cultural and behavioural change. This transition can

be expensive initially, so it may require some capital investment or more costly business, as it requires extensive expenditure both for businesses adopting new models as well as for consumers who might pay a minimum premium price for sustainably produced goods.

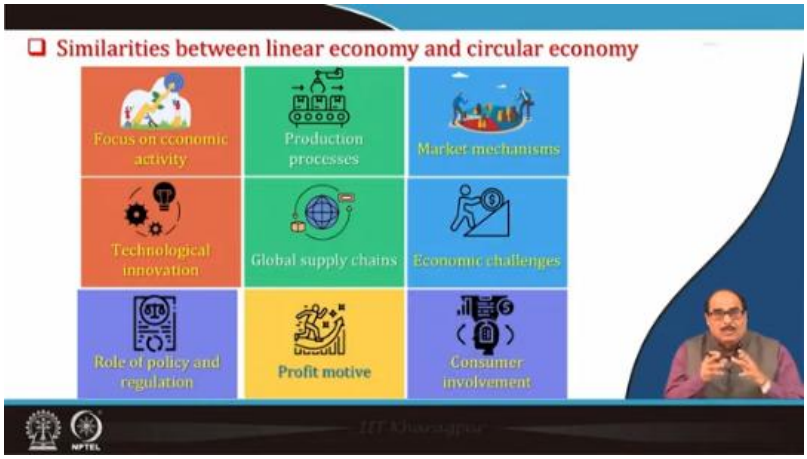


So, it may be a slightly costly affair. However, by using proper practices, one can reduce the cost and also the complexity of the supply chain. Achieving a fully circular economy often involves coordinating complex global supply chains to ensure products return to their origin in a reusable form.



So, this requires a definite complex system management, and one has to have full proof that is the supply chain management or collection of the material for taking it to the industry, for example, even kitchen waste or the food processing industry generates a lot of material. So, there should be a proper mixture of these types, and many of these types may be a mixture of various degradable, biodegradable or non-degradable materials, plastic materials, paper materials, and all those things. So, there has to be a proper system for collection, segregation, and then taking it to the reuse facility, and it is a recycling and

reuse, etc., etc. So, these are the many times, particularly in the food processing industry, that become a challenge.



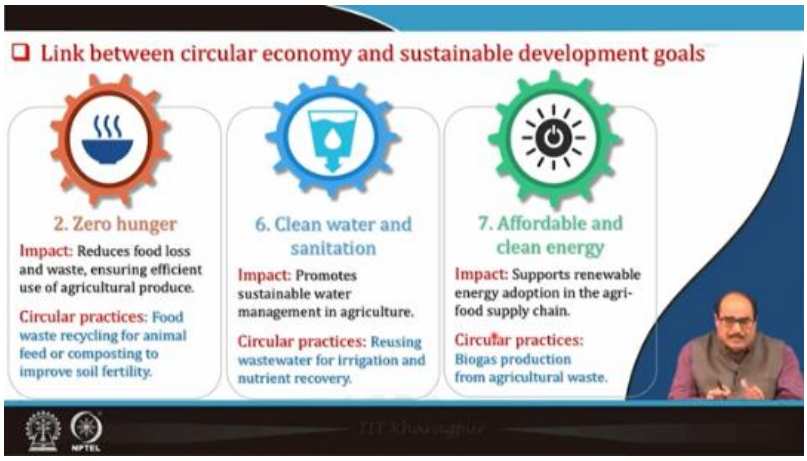
So, if we talk about similarities between linear economy and circular economy, in both economies, the obvious focus is on economic activity, in the case of agriculture and food, such as agricultural production, food processing, and every that involves business, and the major focus is on how to have a good economy.

Then there is a technical innovation in both processes. You need to have advanced technologies, all right. Whether it is a linear economy or a circular economy. Then production processes and global supply chains in both systems—these are the key factors involved, ok. Then market mechanisms and economic challenges in both systems have a role in policy and regulation, like in the linear economy, also some proper policy has to be in place, and this has a proper, permanent, important effect on the output delivery and the product manufacturing, etc., marketing. So, in both systems, in the circular economy also, proper policy guidelines should be there. It will benefit both consumers as well as producers. Then profit motives—in both cases, the main aim of the producer becomes how to earn more profit, and then consumer involvement. Consumers are involved in both the linear economy and the circular economy. So, these are the similarities between these two economies. Then, let us talk briefly about the circular economy and the Sustainable Development Goals. The circular economy and sustainable practices within the food industry play a vital role in advancing sustainable food production systems and resilient agricultural practices.

The circular economy directly aligns with the Sustainable Development Goals by promoting resource efficiency, reducing waste, and fostering sustainability in the agri-food sector. Sustainable development goals are the blueprint to achieve a better and more sustainable future for all by addressing several global challenges, including poverty, inequality, climate change, environmental degradation, peace, and justice.

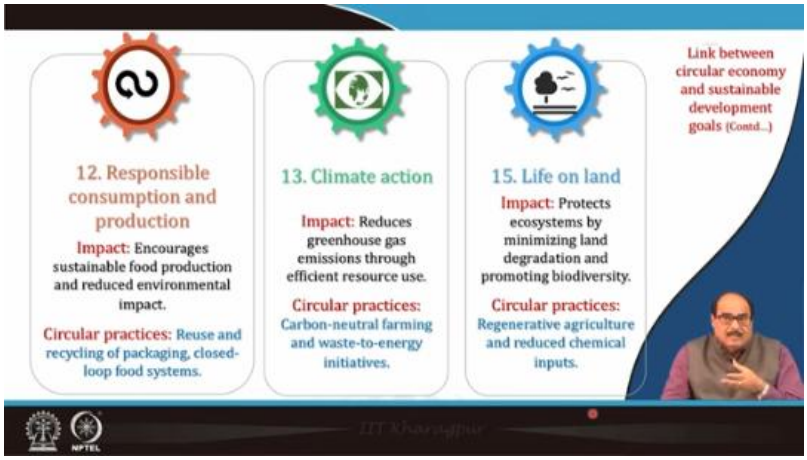
The 2030 Agenda for Sustainable Development, adopted by all UN members in 2015, created 17 Sustainable Development Goals. And what are these 17 Sustainable Development Goals? These are the Global Goals for Sustainable Development, which were part of the 2030 Agenda, and they include: number 1, no poverty. By 2030, poverty should be completely alleviated. Then, zero hunger is number 2; number 3 is good health and well-being; 4 is quality education; then number 5 is gender equality. Number 6, clean water and sanitation; then, affordable and clean energy, decent work and economic growth is number 8. Number 9 is industry, innovation, and infrastructure; then reduced inequalities. Sustainable cities and communities. Then, number 12 is responsible consumption and production; number 13, climate action; number 14, life below water; number 15, life on

land; number 16 is peace, justice, and strong institutions; and number 17 is partnerships for the goals. So, these are the 17 goals for sustainable development set by the UN. Almost all these goals are related to food and agriculture in some way or. So, particularly that which we have a direct connection with the food and agriculture, particularly the food processing.

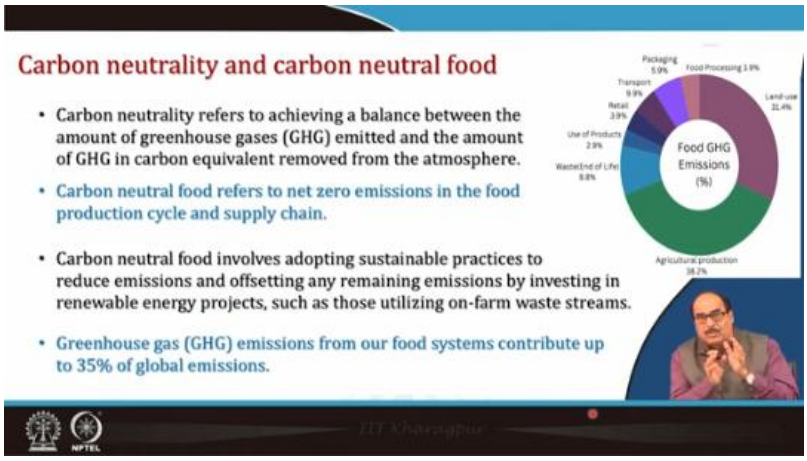


We just want to briefly let you know what those links are between the circular economy and the Sustainable Development Goals. So, number two, that is zero hunger, has an impact on the development of sustainable development, which reduces food loss and waste, ensuring efficient use of agricultural produce. So, what are the circular practices in this case, that is, the food waste recycling for animal feed or composting to improve soil fertility? So, that is the circular economy. Then, in clean water and sanitation, it promotes sustainable water management in agriculture, and here the circular practices may be reusing wastewater for irrigation and nutrient recovery. In the case of affordable and clean energy, which supports renewable energy adaptation in the agri-food supply chain, the circular practices here may include biogas production from agricultural waste. Then number 12 is the responsible consumption and production, and this encourages sustainable food production and reduces the environmental impact.

In this case, the circular practices may be the reuse and recycling of packaging, a closed-loop food system, etc. Then, in climate action, it reduces greenhouse gas emissions through efficient resource use. The circular practice in this case may be carbon-neutral farming and waste-to-energy initiatives. Then number 15, life on land, protects the ecosystem by minimising land degradation and promoting biodiversity. So, here the circular practices may be regenerative agriculture and reduced chemical inputs in agriculture.

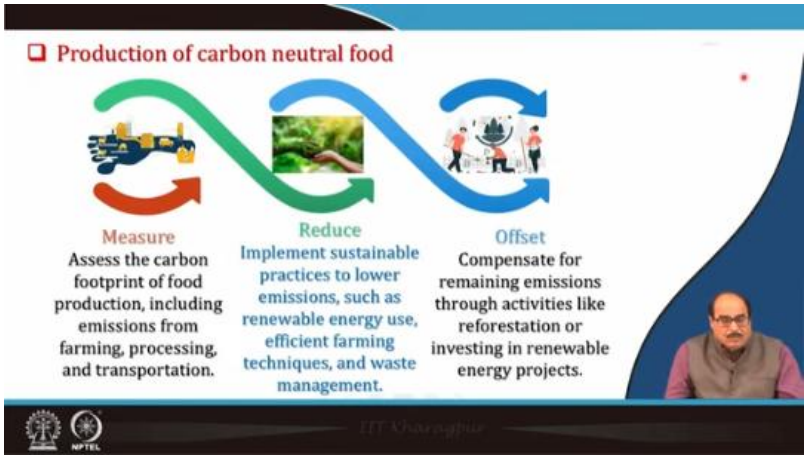


So, these are some of the examples of a direct link between the circular economy and the Sustainable Development Goals. Then let us see what carbon neutrality is and what carbon-neutral food is. The carbon neutrality refers to achieving a balance between the amount of greenhouse gases that is the greenhouse gases that are emitted and the amount of greenhouse gases in carbon equivalent removed from the atmosphere. So, that is what is the there should be a proper balance between these two that mean by carbon neutrality.



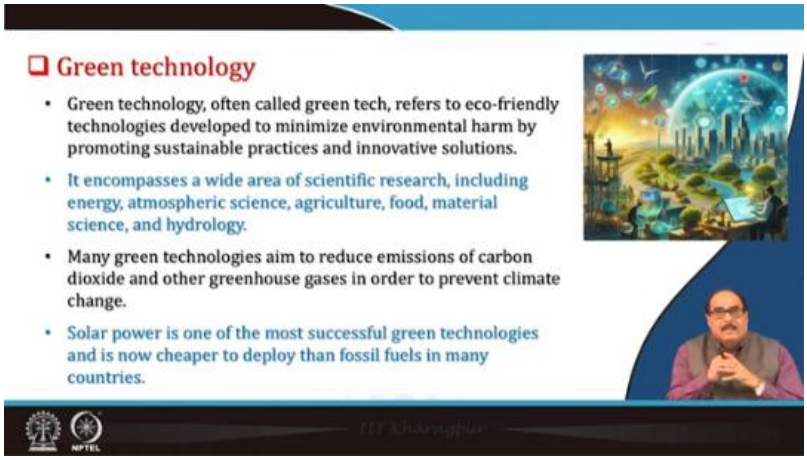
Carbon-neutral food refers to net-zero emissions. In the food production cycle, as well as the supply chain. It does not lead to any environmental pollution, etc. There should be almost 0, at least if not 0, minimum, and if it is 0, that is nothing better than that 0 emissions. Carbon neutral foods involve adopting sustainable practices. To reduce emissions and offset any remaining emissions by investing in renewable energy projects such as those utilizing on-farm waste streams, etcetera. And if you look here, it is shown that greenhouse gas emissions come from the food system. From our food system, the greenhouse gases vary, such as water at 8.8 percent, use of product at 2.9 percent, packaging at 5.9 percent, and food processing at 3.9 percent. So, if you look at the data in the literature, greenhouse

gas emissions from the food system contribute up to about 35 percent of global emissions from all systems. So, what is the production of carbon-neutral foods? To achieve environmental balance with zero emissions, we should take certain measures to produce carbon-neutral foods, and these measures are: measure, reduce, and offset. These are the three strategies.

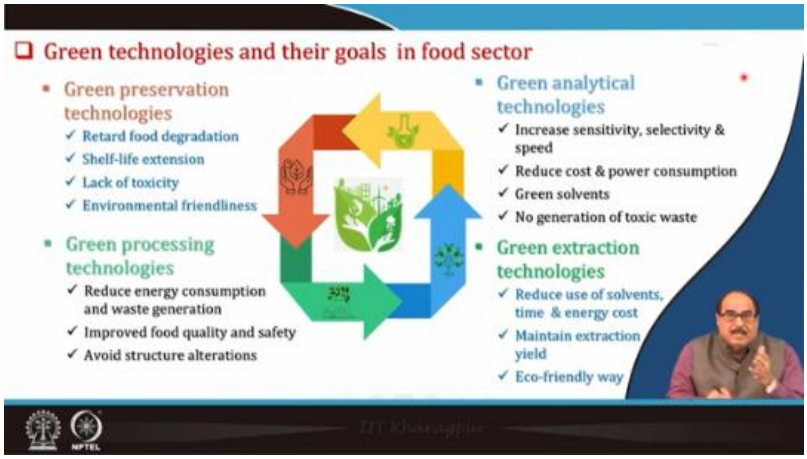


Measure means assessing the carbon footprint of food production, including emissions from farming, processing, and transportation at all points in the value chain. Then, implement sustainable practices to lower emissions at each point in the value chain, like renewable energy use, efficient farming techniques, waste management, etc., that should be implemented and followed to reduce emissions. Finally, offset—compensate for remaining emissions through activities like reforestation or investing in renewable energy projects, etcetera.

So, that should be the strategy for the production of carbon-neutral food: measure, reduce, and offset. Then, green technology—often also called green tech—refers to eco-friendly technologies developed to minimise environmental harm by promoting sustainable practices and innovative solutions. It encompasses a wide area of scientific research, including energy, atmospheric science, agriculture, food, material science, and hydrology.

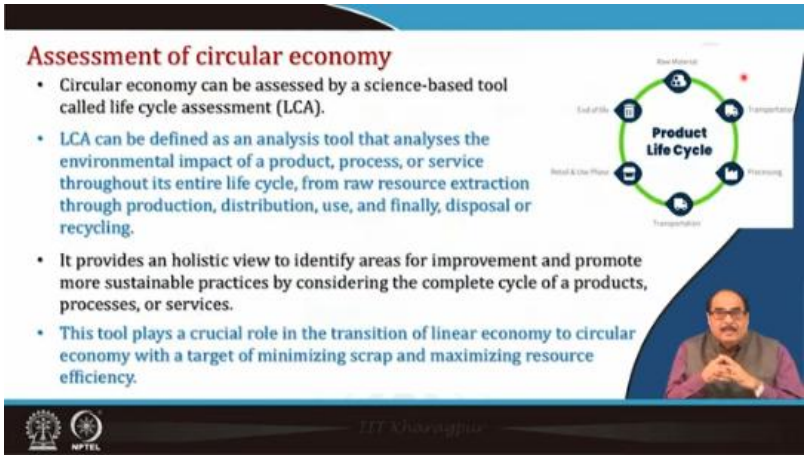


Many green technologies aim to reduce emissions of carbon dioxide and other greenhouse gases to prevent climate change. Solar power is one of the most successful green technologies and is now cheaper to deploy than fossil fuels in many countries. So, such systems should be promoted. So, green technologies and their goals in the food sector. Green preservation technologies, such as biopreservation and other methods, can be used.

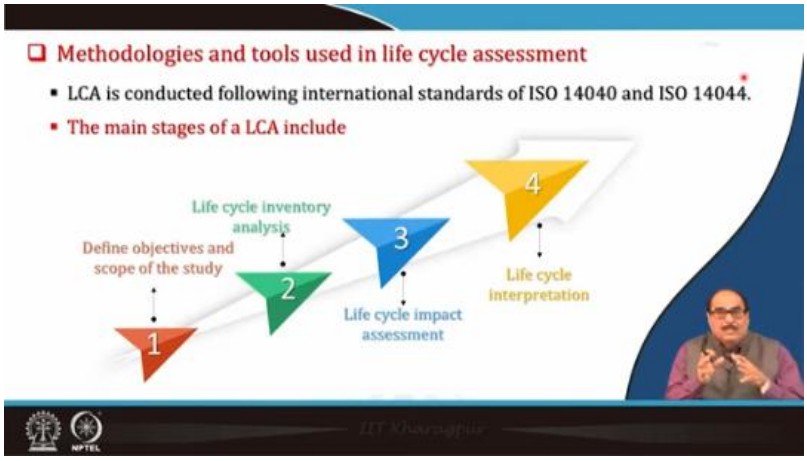


It retards food degradation, extends shelf life, lacks toxicity, and is environmentally friendly. Then, green processing technologies like ohmic heating, electrical technologies, radiation technologies, or other non-thermal technologies reduce energy consumption and waste generation in many cases, improve food quality and safety, and avoid structural alterations in most cases. Then, green analytical techniques like increased sensitivity. They result in selectivity and speed, reduce cost and power consumption, and here, many times, green solvents, etc., are used for these analytical purposes, and therefore, there is no generation of toxic waste. Then, green extraction technologies like reduced use of solvents, time, and energy cost, for example, supercritical carbon dioxide, subcritical extractions,

and all those things, and they maintain the extraction yield as they are also eco-friendly. There should be many times to have this fact that we need to assess the circular economy.

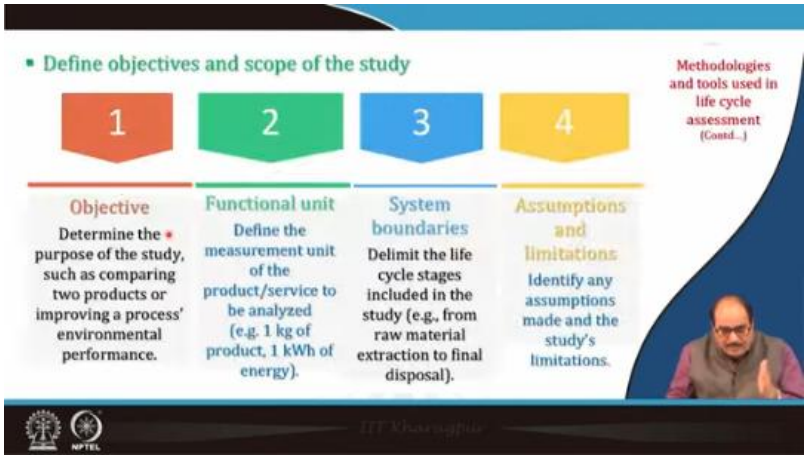


So, this circular economy can be assessed by a science-based tool that is called life cycle assessment. This life cycle assessment can be defined as an analysis tool that analyzes the environmental impact of a product, process, or service throughout the entire life cycle, from the raw resource extraction through production, distribution, use, and finally, disposal or recycling. It provides a holistic view to identify areas for improvement and promote more sustainable food practices by considering the complete cycle of a product, process, or service. And this tool plays a crucial role in the transition from a linear economy to a circular economy, targeting minimising scrap and maximising resource efficiency.

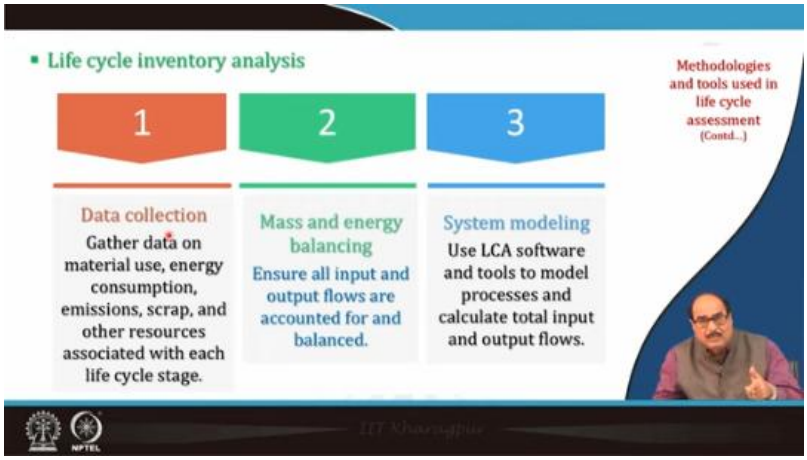


So, the methodologies and tools that can be used for the life cycle assessment, such as the international standards, such as ISO 14040 and ISO 14044, are the international standards which are used for LCA life cycle assessment. The main stages of an LCA may include the first step, which is to define objectives and the scope of the study. Then go for the life cycle

inventory analysis, third step is the life cycle impact assessment and finally, you have the life cycle interpretation. For example, we will take a little bit about this, like in the first stage, we define the objective and scope of the study.

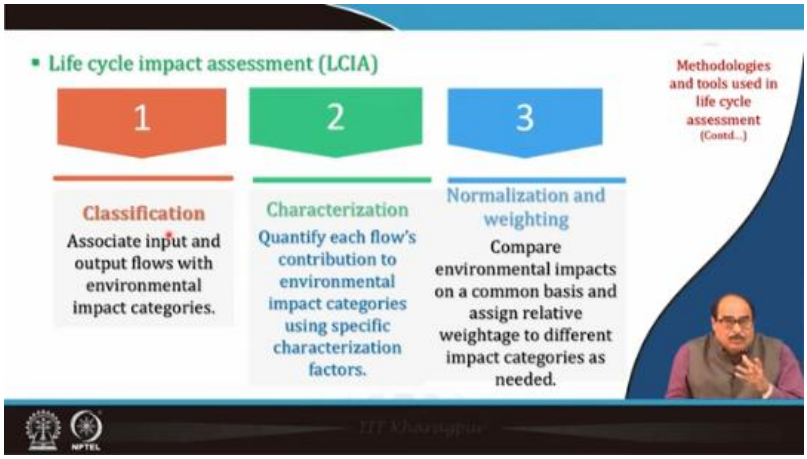


These may be the strategies that are the objectives, such as determining the purpose of the study, such as comparing two products or improving a process's environmental performance, etc. Then decide the functional units, like defining the measurement of the product or service to be analysed, such as 1 kg of the product or 1 kilowatt hour of energy, and so on. Then define system boundaries. That is to delimit the life cycle stages, including the study, from raw material to extraction to final disposal. And then finally, the assumption and limitations identify any assumptions made and the study limitations. So, these are the clear-cut steps one should define the objective and scope of the study.

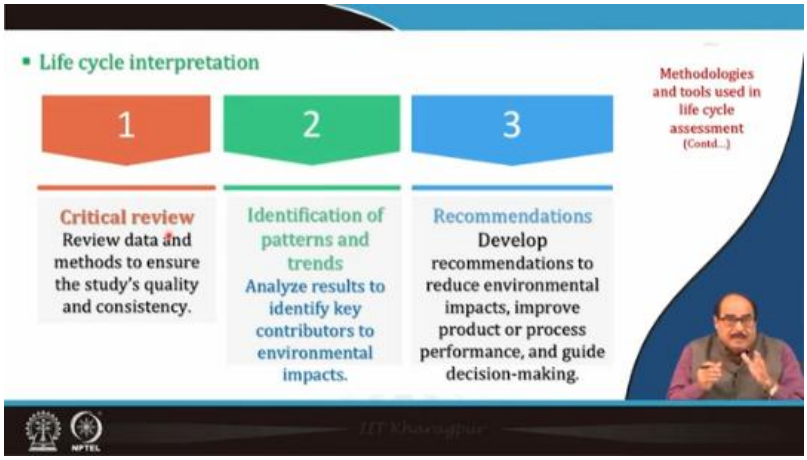


Then go for the life cycle inventory analysis, which involves data collection. mass and energy balancing and system modelling. In the data collection, it means what one needs to do by having a proper method to generate data and material use, energy consumption,

emissions, scrap, and other resources associated with the life cycle stage. And then ensure all the input and output flows are accounted for and balanced, and then finally, use LCA software and tools to model the process and calculate the total input and output flows.

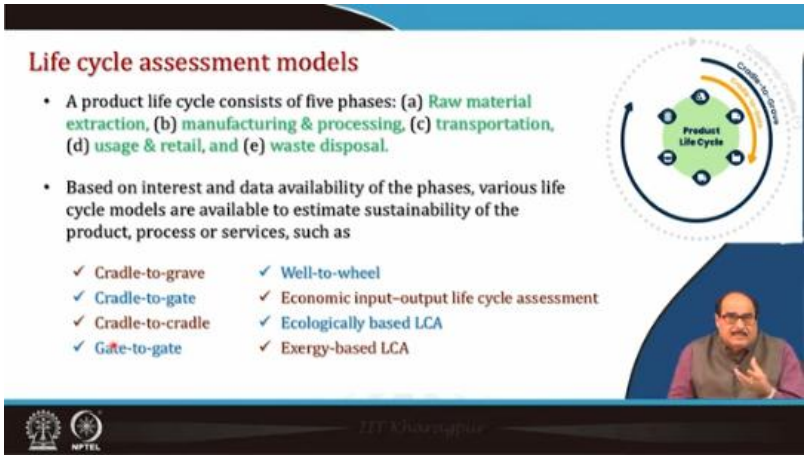


Then go for the life cycle impact assessment, and this involves classification, characterisation, normalisation, and weighting. In the classification, what do you need to do? You need to associate input and output flows with environmental impact categories. Then quantify each flow's contribution to environmental impact categories using specific characterisation factors. And then finally, compare the environmental impact on a common basis and assign relative weightage to different impact categories as needed.

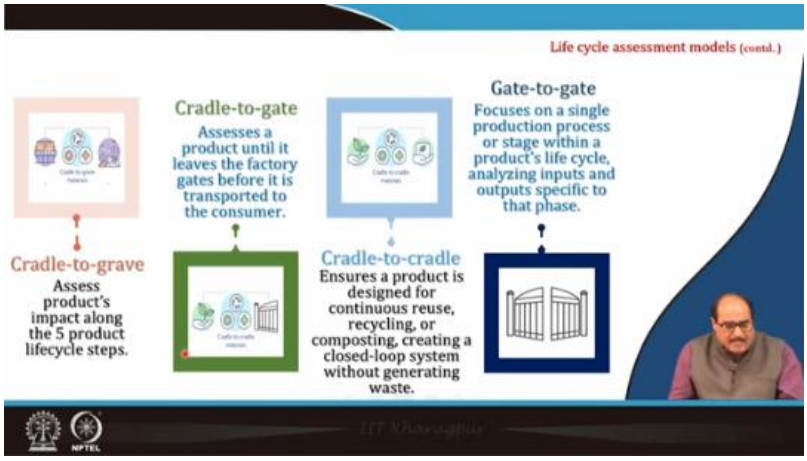


Then we come to the life cycle interpretation, and it involves critical review, identification of patterns and trends, and finally, recommendations. In the critical review, what you need to do is review data and methods to ensure the study's quality and consistency. Analyze results to identify key contributors to environmental impacts, and finally, develop

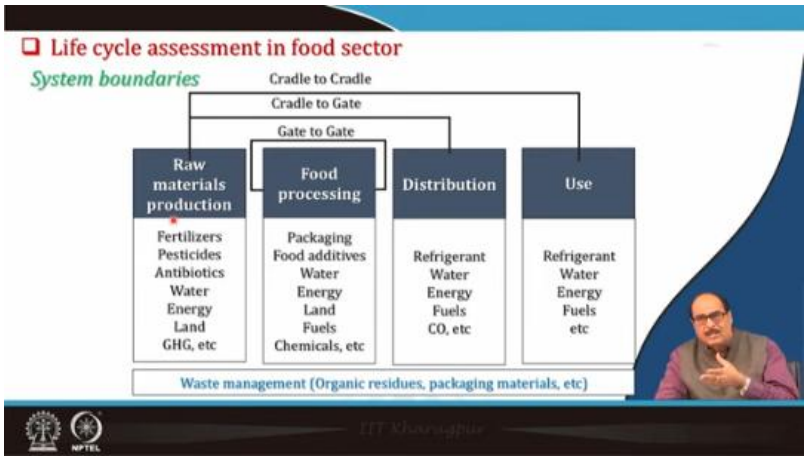
recommendations to reduce environmental impact, improve product or process performance, and guide decision-making.



So, there are various life cycle assessment models that consist of 5 phases. A product life cycle consists of 5 phases, such as the raw material stage, which includes raw material extraction, raw material sourcing, then manufacturing and processing, followed by transportation, use and retail, and finally, waste disposal. So, these are the clearly defined 5 phases of a product life cycle. Now, based on the interest and data availability of the phases, various life cycle models are available to estimate the sustainability of the product, process, or service. These models may include cradle to grave, cradle to gate, cradle to cradle, gate to gate, well to wheel, economic input-output life cycle assessment, ecological balance life cycle assessment, energy-based life cycle assessment, and so on. So, you need to focus on what your main objective is. In various cases, different models can be used. I will elaborate a little bit.

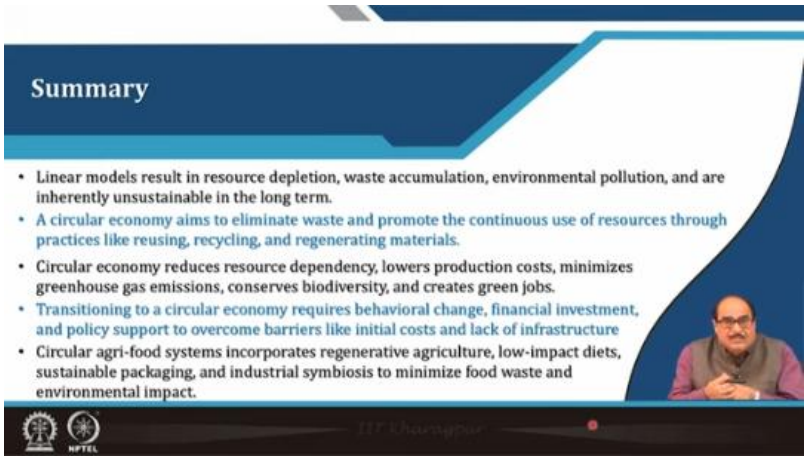


For example, cradle to grave assesses a product's impact along the 5 life cycle steps we have seen earlier. So, when you talk about cradle to grave, it impacts all 5 life cycle steps. Whereas, cradle to gate assesses a product until it leaves the factory gate before being transported to the consumer. Cradle to fabricate involves measuring the complete greenhouse gas emissions and ensuring what should be done to achieve net-zero emissions. Then cradle to cradle ensures a product is designed like cradle to cradle ensures a product is designed for continuous reuse, recycling or composting. Creating a closed-loop system without generating waste. Then even gate to gate means it focuses on a single production process like gate to gate inside the factory within the factory everything should be done to ensure that there is a no waste generation, no employment pollution, no there is pollution of the environment or other things like 0 emissions that is production process or stage within a producer products life is kind.



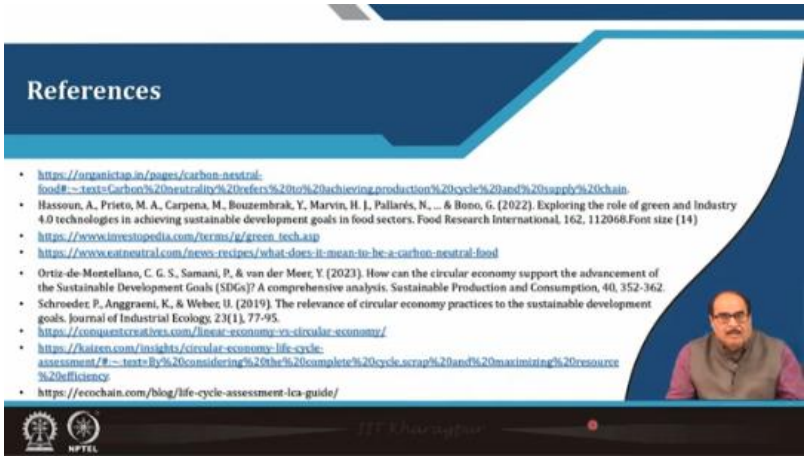
So, analysing inputs and outputs is specific to that particular phase, which is the gate-to-gate. For example, I will just show you that it is a life cycle assessment in the food sector with a product. So, in the food sector, there is a use of raw materials and production, such as fertilisers, pesticides, antibodies, water, land, greenhouse gases, etc., all of which are associated with the production of raw materials. Then these raw materials are taken to the factory for food processing purposes, and where various things like packaging, food additives, water, energy, land, fuels, chemicals, etc., are the inputs or sometimes outputs that are taken. Then from the factory it goes to the distribution, where the refrigerant, water, energy, fuels, gases, carbon monoxide, etc., these are the gases that may be involved. and then in the use of even refrigerant water, energy, fuels, etc. So, this is one of the best and finally, the waste management, then organic residue packaging material, etc. So, in this case, these are the different stages. So, you can see that when we talk about cradle to cradle, it means that starting from raw material production and till this is used in whatever steps

in this, they should be properly and effectively managed. So, as to make sure that there is no pollution, no greenhouse emissions. That is the life of the product, which is good. Then, when we talk about cradle to gate, it means there is a raw material production through distribution, it has gone to the till, and then finally, if you talk about gate to gate, it means within the food processing. that is the material once it is registered. So, gate to gate means within it is one confined step, and where we are taking, we are assessing that is how the product life cycle is there and how it is emitting gases, etc., whatever. So, that is data is generated and it is analysed and makes sure and also the major aim is to ensure good practices, good laboratory practices, good manufacturing practices, good hygienic practices, and good other practices. So, to make sure that all the products are good in quality, they are safe, and there is no emission of gases or environmental pollution.



So, finally, I would like to summarise the lecture by saying that the linear economic models result in resource depletion, waste accumulation, environmental pollution, etc., and these are inherently unsustainable in the long term. So, a circular economy. A circular economy aims to eliminate waste and promote the continuous use of resources through practices like reusing, recycling, and regenerative materials. A circular economy reduces resource dependency, lowers production costs, minimizes greenhouse gas emissions, conserves biodiversity, and creates green jobs. However, transitioning to a circular economy requires behavioural change, financial investment, and policy support to overcome barriers like initial costs and lack of infrastructure. Circular agri-food systems incorporate regenerative agriculture, low-impact diets, sustainable packaging, and industrial symbiosis to minimize food waste and environmental impacts.

So, these were the references used to prepare this lecture.



Finally, thank you all for your patience in listening. Thank you very much.