SUSTAINABLE MINING AND GEOINFORMATION

Prof. Basanta Kumar Prusty

Department of Mining Engineering

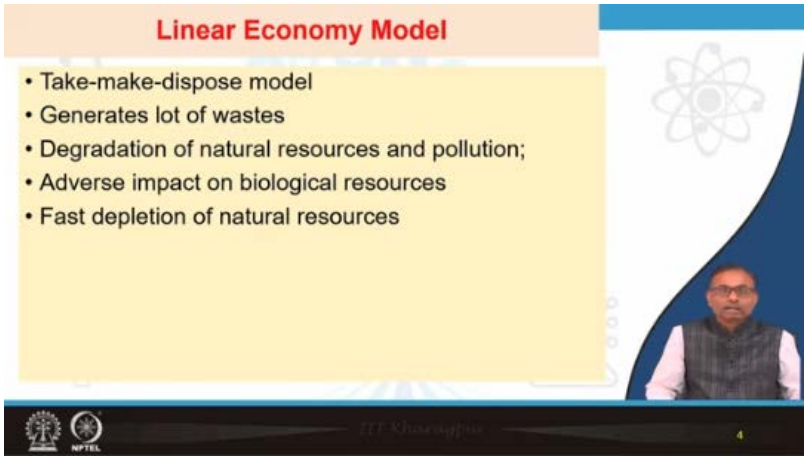
Indian Institute of Technology Kharagpur

Week – 11

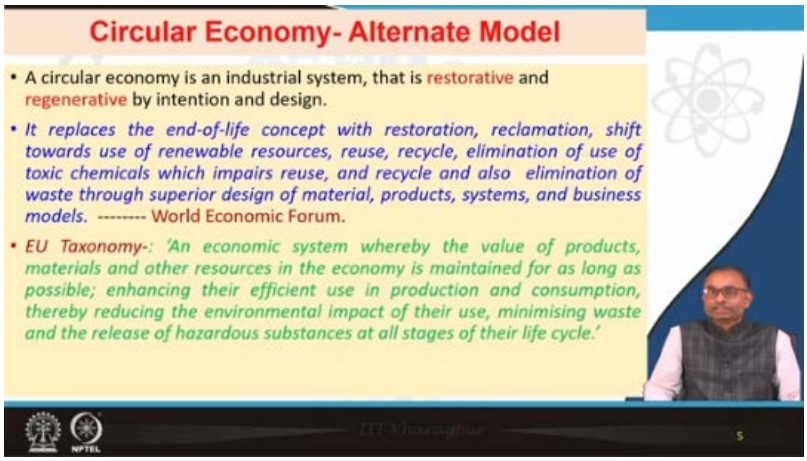
Lecture 51: Circular Economy for Mining Industry-I

Welcome, student, to the fifty-first lecture of our NPTEL course on Sustainable mining and Geo information. Today, we are starting a new topic, and the name of the topic is the Circular Economy. So, the Circular economy for the mining industry is the topic that we are going to discuss today. So, the concept covered during today's class will be defining the circular economy. What do we mean by circular economy? Circular economy versus linear economy, the need for circular economy, principle of circular economy, benefits of circular economy, challenges to circular mining, and how we can implement the concept of circular economy in the mining and mineral industry. So, these are the topics that we will be covering, and we shall cover these topics in our two classes or maybe three classes. So, to start with now presently the economic model that is being used worldwide. Not only in the mining sector, but also overall in the other sectors, it is also what is known as a linear economy model. So, we can see this diagram for the linear economy model, and in the linear economy model, the different components or the sequence are like we extract the mineral resources or other resources from Mother Nature. The mineral resources are extracted from the mines, and they are transported to the manufacturing industry, where we are producing various product parts and components.

These products are transported from the manufacturing unit to the user point, to the consumer, to different industries, and households, where they are used, and these products have a certain life span. The product serves for a particular time period. It could be a few months to a few years or several years. Whatever the lifespan is, depending on the product, the consumer or the consuming industry uses the product or part that was manufactured by the manufacturing unit. It is used as long as there is useful life left in the product. So when the useful life is completed or exhausted, the product is no longer usable, and then that discarded product will be wasted. It will be taken to a disposal site, landfill site, where it will be disposed of. Previously, we have discussed the life cycle. So, basically, what we are showing here is the life cycle in the linear economy model from mines to the disposal site. This is the lifespan of the product, and in the linear economy model, we mine, produce the material, use the material, and waste the material. The linear economy model is also called the take, make, dispose model. In the linear model, once the productive life of the product is over, we dispose of it, and so, it becomes waste material.



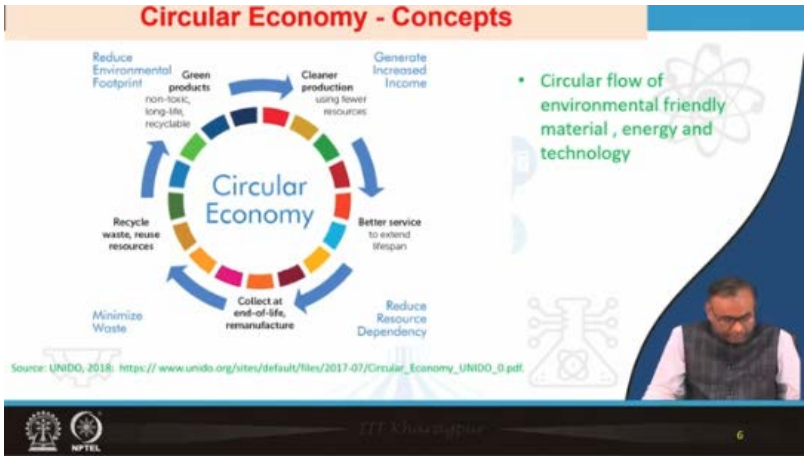
So, in the linear economy model, we are generating a lot of waste, and as you know, when you are generating a lot of waste and when you are disposing of the waste material in the environment, there will be bound to be degradation of the environment. There will be pollution, and your natural resources, like air, water, soil, and biological resources, will be degraded. There will be an adverse impact on the biological resources, there will be an adverse impact on the ecology and ecosystem. And another important thing is that because you are consuming, you are mining the mineral resources, and gradually, there will be depletion of the natural resources. Remember that mineral resources are a finite quantity. They are not infinite. So, when you are extracting the mineral, producing the product, and then using and disposing of it. So, gradually, we are depleting the natural resources, the mineral resources. Now, we have discussed what a linear economy model is. This linear economy model is causing the depletion of natural resources, which is causing environmental degradation. Since we are talking about the topic of sustainable development, the philosophers and economists who are more concerned about the economy have now proposed an alternate system of industrial economy.



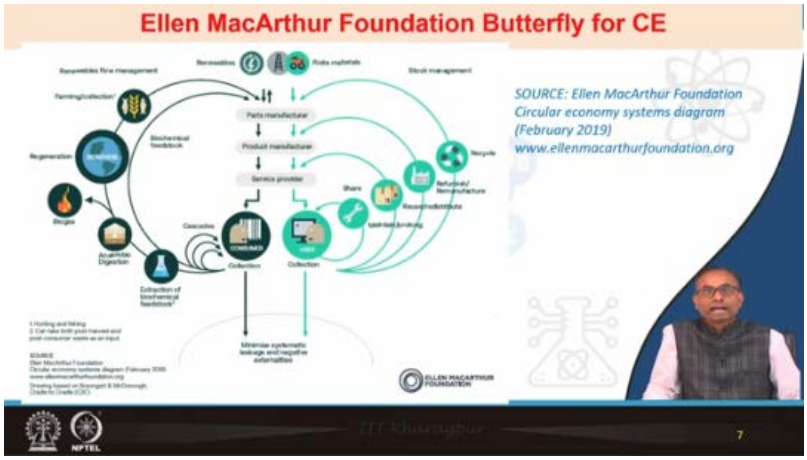
The name of this alternative economic industrial model is known as the circular economy. So the linear economy is one-directional. It moves from a mining unit and ends up at the disposal site. But in the circular economy, this is an industrial system that is restorative and regenerative by intention and purpose. So basically, we are taking inspiration from nature, we are taking inspiration from the regenerative, restorative, and renewable properties of the various natural resources. The World Economic Forum has given a definition of the circular economy. As per the WEF, circular economy replaces the end of life concept with restoration, reclamation, and shift towards use of renewable resources, including renewable energy, then reuse, recycle, elimination of use of toxic chemicals, which empowers reuse and recycle, and also elimination of waste through superior design of material product system and business model. So, this is the definition of the circular economic model as per the World Economic Forum. Now, the EU Taxonomy has defined the circular economy in a different language. As per them, it is an economic system whereby the value of the products and other resources in the economy are maintained for as long as possible, enhancing their efficient use in production and consumption, thereby reducing the environmental impact and their use, minimizing waste generation, and minimizing the release of hazardous substances at all stages of their life cycle.

So, there are other definitions also. I will show a definition here, this will give an idea. If you look at the pictorial model suggested by UNIDO in the year 2018, they have explained the concept of circular economy using the diagram that you can see. Here you can see, In the circular economy, we are basically producing greener products. The mineral resource we are mining, and we are designing and producing greener products. Greener product means that the environmental impact is less, and we are using renewable sources of energy. We are using a non-toxic, long-life, recyclable product. We are producing a recyclable product. We are producing greener products through cleaner methods of production. The cleaner method of production will be using less resource than what is used for the linear model. And through better service, we are extending the lifespan of the product by reusing, recycling, remanufacturing, and redesigning. There are different R concepts; there are nine different types of R. And through better service, we are extending the lifespan of the product by reusing, recycling, remanufacturing, redesigning. There are different R concepts are there, nine different types of R are there. We know, popularly, the three R: reduce, reuse, recycle, but now some more concepts have been proposed. Using these different 9 R, we can extend the lifespan of the product, and then after the end of the lifespan, we collect the material for recycling or

remanufacturing. So, we are not disposing of that material in the landfill site. But there is a collection system where all the used products will be collected for recycling, for remanufacturing. And again, they will be used for the remanufacturing of the product. So this is how the metal or the material will be moving in a circle with a never-ending cycle.



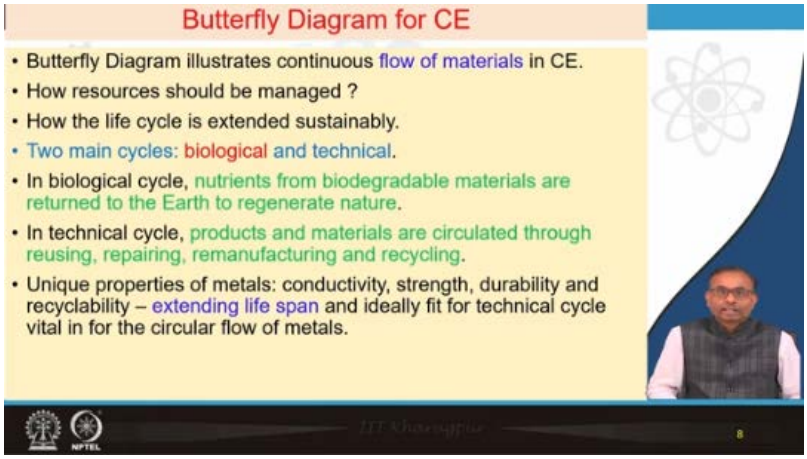
There is a collection system where all the used products will be collected for recycling, for remanufacturing. And again, they will be used for the remanufacturing of the product. So this is how the metal or the material will be moving in a circle with a never-ending cycle. That is the concept of circular economy. So there will be minimum waste, less waste, and also there will be less environmental footprint. So this is the circular flow of environmental friendly material, energy and technology. Using this will reduce our resource dependency, minimize waste production, reduce environmental footprint, extend the lifespan of the product, and also help generate increased income for the people. So, this is the concept of the circular economy. So, this is the concept of the circular economy. Now, there was another conceptual diagram, which was suggested by the Ellen MacArthur Foundation, known as the butterfly diagram for the circular economy. So, if you look at this diagram, you can see we are taking inspiration from the nature of the restorative property of nature. So, you can see the biological resources; these biological resources take the nutrients from nature, from the soil, from the water, from the air. They grow and after the end of their life, they come back to nature, to the soil, to the water, to the ecosystem.



So, this flow of biological nutrients in nature, we are trying to mimic in industrial life or the industrial cycle. So, in the industry, you can see that you are producing a product in a manufacturing industry. You are taking it from the mineral input producing the metal and you are producing a product. And then on minerals, metals you are inputting the energy. Other type of elements like water, chemicals also you are inputting, processing, and manufacturing the product. These are called technical nutrients. Now, the product has a certain lifespan. After the product life, the qualitative life of the product has reduced. You are not disposing of it; rather, you are taking it to a maintenance unit. You are taking it to a place where there will be remanufacturing, where there will be reuse. And the refurbished, remanufactured product will be coming back to the consumer with an extended lifespan. And when the technical quality of the refurbished, remanufactured product is completely over, then it comes to a recycling facility. Here we are mostly talking about the metals, so these metals will be recovered, and again, they will be used for the manufacture of the new product.

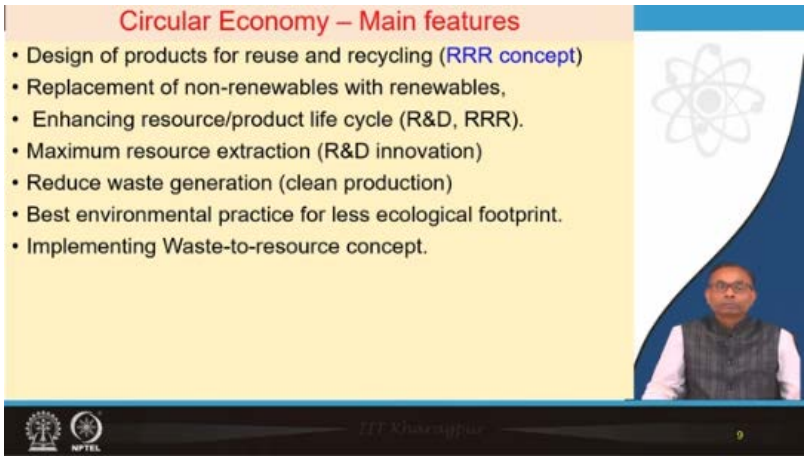
So the metal or the mineral will be undergoing a circular flow, just like the biological nutrient is undergoing a nutrient cycle. Here, it will undergo a technical nutrient cycle. So, in this butterfly diagram, left side, you have the biological nutrient, circular flow or cyclic flow of biological nutrient, and on the right side, you have the circular flow of the technical nutrients. So, this is the Alan Macarthur Foundation butterfly diagram, and this is what we are trying to achieve in a circular economic model, where there will be a circular flow of energy, of the material, of the metal; so that there will be less environmental damage, there will be less waste generation. So, this is the fundamentals of what we mean by circular economy. Now I have already discussed that the butterfly diagram illustrates the continuous flow of material in the circular economy, how resources should be managed, and how the life cycle of the product is extended. There

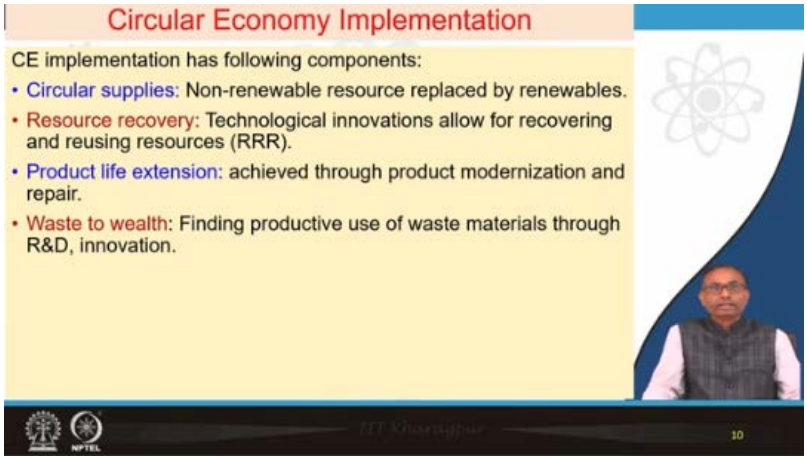
are two main cycles, the biological cycle and the technical cycle. In biological cycles, nutrients from biodegradable materials are returned to nature, to the earth, to the soil, to the water, to be regenerated by nature. In the technical cycle, products and materials are circulated through reusing, repairing, remanufacturing, and recycling. Now metals have unique properties like conductivity, strength, durability, and recyclability. Because of these unique properties, it is possible to extend the lifespan, and metal can ideally fit in the technical nutrient cycle, which is vital for the circular flow of the metal and for the circular economy model. The main features of the circular economy, the design of products for reuse and recycling. So, we are using the RRR concept.



The replacement of non-renewables with renewables, particularly renewable energy, is used. If you can use renewable energy, it will support green product development. Enhancing resource or product life cycle, enhancing the lifespan of the product through research and development, through the RRR concept. Maximum resource extraction from nature, from the minerals, that is, through R&D, technological development. Reduce waste generation, that is, cleaner production. The best environmental practice to be followed for a smaller ecological footprint is to implement the waste-to-resource concept. So, this is the main feature of the circular economy. Now, when we are implementing the circular economy, we have to have circular supplies. Non-renewable resources should be replaced by renewable resources, particularly taking the example of energy. Then comes maximum resource recovery. In mineral resources, there is a cut-off grade. Lesser than the cut-off grade, it is waste material, and more than the cut-off grade, we call it a resource, and we are wasting the waste material where there is metal content, so we have to develop the technology. We have to be innovative so that we recover maximum resources, maximum metal content, and reuse the resources optimally. Product life extension is achieved through product modernization, repairing, remanufacturing, and for

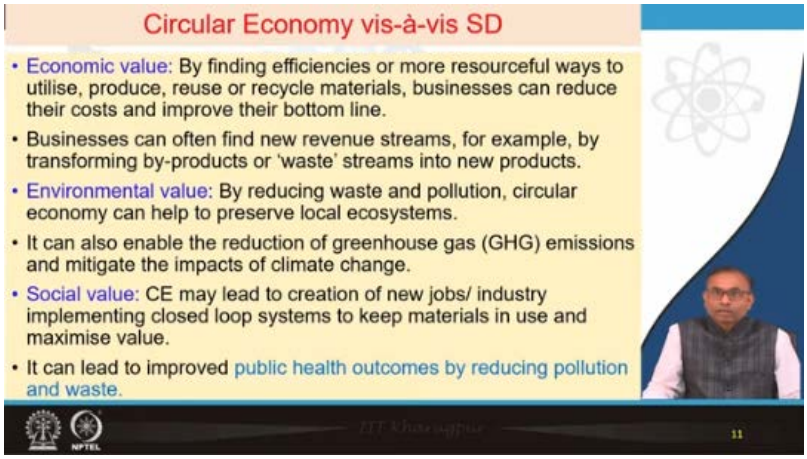
all this, technological innovation is necessary. And lastly, waste to wealth. The mineral industry produces a lot of waste material. So, how can we do a productive use of this waste material of the mining industry through the development of different types of products, useful products from this waste material through R&D and innovation?





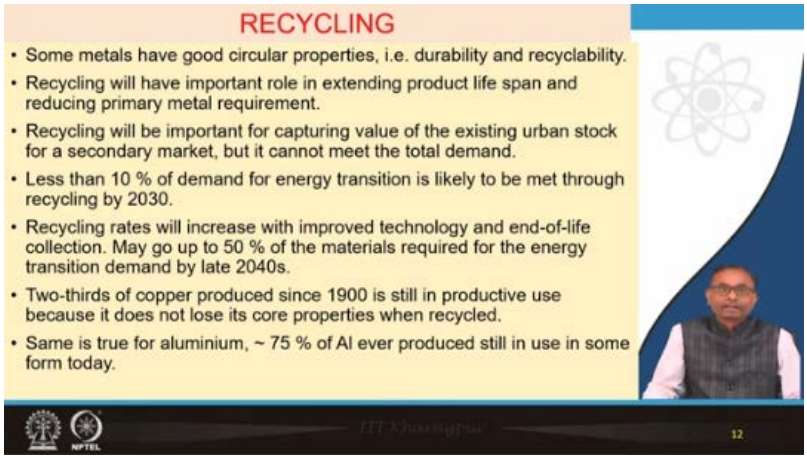
Now, the circular economy vis-à-vis sustainable development. We have previously discussed the concept of sustainable development and how the circular economy helps achieve it. Sustainable development has three main pillars: the economic pillar, which supports the economy; the environmental pillar, which reduces environmental degradation from mining; and the social pillar, which benefits society. So, you will see that the circular economy also aids economic development by reducing environmental impact and improving socioeconomic conditions. Economic value is increased by finding efficiencies or more resourceful ways to utilize mineral products, reuse or recycle materials, and businesses can reduce costs and improve profits or their bottom line. That is one goal. Businesses can often discover new revenue streams. For example, by transforming by-products or waste streams into new products and generating revenue by

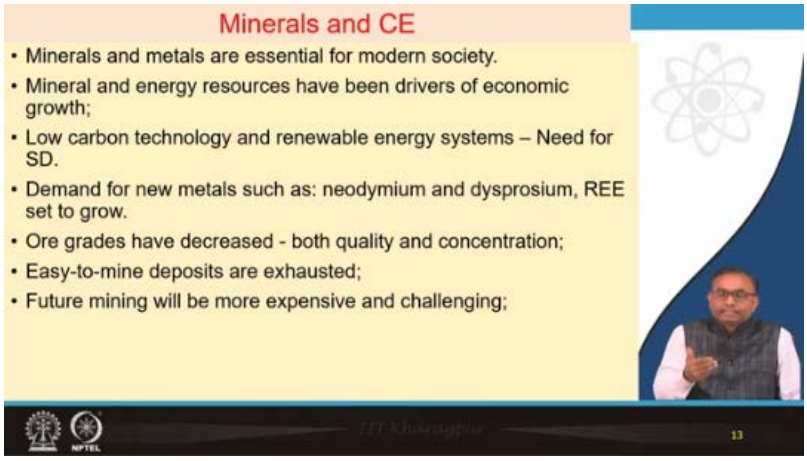
selling them. The environmental value of the circular economy: By reducing waste and pollution, the circular economy helps preserve ecosystems and the environment. It can also reduce greenhouse gas emissions and mitigate the impact of climate change. Social value: The circular economy may lead to the creation of new jobs and industries by implementing closed-loop systems to keep materials in use and maximize their value due to reduced waste generation and environmental preservation. Also, in the social sphere, it can improve public health outcomes by reducing pollution and waste. Now, recycling is one of the critical components of the circular economy. Particularly concerning metals, some have excellent circular properties, such as durability and recyclability.



Recycling plays an important role in extending a product's lifespan and reducing the need for primary metals. Recycling is crucial for capturing the value of existing materials in urban stock for secondary markets. We have primary mining and secondary mining. Primary mining extracts from mines, while secondary mining involves recovering metals from waste disposal sites. There are many metals available in disposal sites. Extracting these metals from waste sites is called secondary mining, also known as urban mining. Less than 10% of the demand for energy transition is likely to be met through recycling. However, with technological advancements, this recycling rate will increase. It may reach up to 50% for metals used in energy transition by the late 2040s. Two-thirds of the copper produced since 1900 remains in productive use because copper retains its core properties when recycled. Similarly, 75% of all aluminum ever produced is still in use through recycling. Recycling will be a critical component of the circular economy. Regarding the minerals and mining sector and the circular economy, minerals and metals are essential for modern society, and mineral and energy resources have driven economies. Low-carbon technologies and renewable systems are critical for both the circular economy and sustainable development. Demand for new metals such as

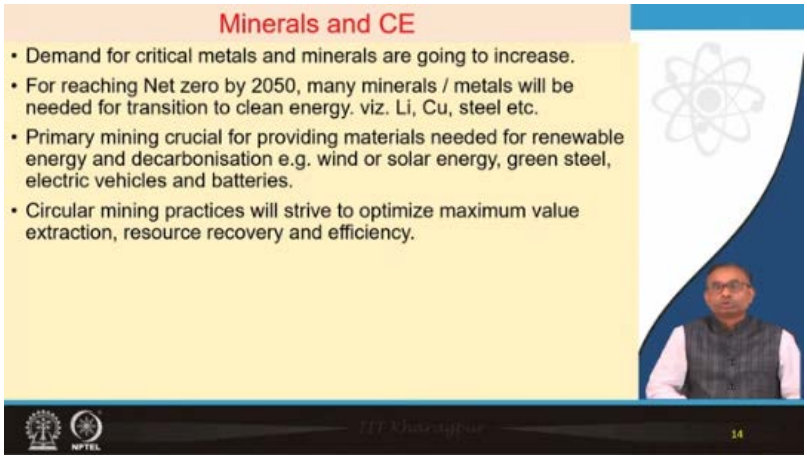
neodymium, dysprosium, rare earth elements, and other critical minerals essential for the digital and circular economy is set to grow. In India, industries have exhausted high-quality ore grades in mines.

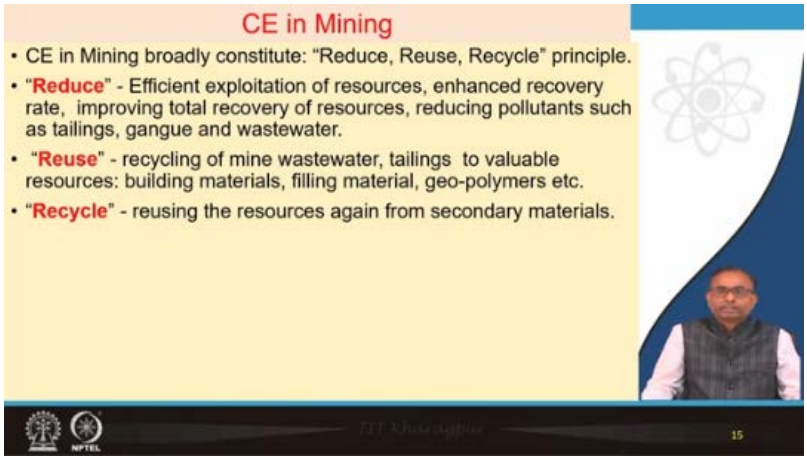




Now, poorer-grade ores in difficult geological conditions must be used. Easy-to-mine deposits are exhausted. Future mining will be more expensive and technically challenging. In this context, demand for critical metals and minerals will increase as we transition to green energy. We are transitioning to renewable energy and a digital economy. Many critical metals and minerals will be essential for the circular economy, and we aim for net-zero emissions by 2050 or 2070. Metals such as lithium, copper, and steel will be crucial for the clean energy transition. Primary mining will be vital for providing materials needed for renewable energy and decarbonization measures. Some critical minerals and metals will be particularly important in the shift to clean energy, such as solar energy, green steel, electric vehicle batteries, etc. Demand for these critical minerals will increase. Circular mining practices will strive to optimize value extraction, resource recovery, and efficiency. Currently, the circular economy concept in mining is

not fully explained. A well-defined framework must be developed, and it is still in progress. It is an evolving science. However, as of today, what is understood is that more applications of





RRR in the mining sector: Reduce, Reuse, and Recycle principle. That will lead to the circular economy and circularity in the mining industry. Reduce: When you reduce your resource requirement, it enables efficient exploitation of resources, enhanced recovery of minerals, improved total recovery of resources, and reduced pollution, such as tailings. Gangue and wastewater. That is the reduce, reuse, and recycling of mine wastewater, recycling of tailings into valuable resources, recycling or reuse of building materials, reuse of filling material, and reuse of geopolymers. This is how the reuse and recycling of different metals coming from secondary mining. Whatever minerals and metals are extracted will be recycled to produce new metals and new metallic products. So, the concept of 3R is useful. And there are many R's we will discuss in the next class. But primarily, these three R's—reduce, reuse, and recycle—will be used in mining. Then it will lead to the circular economy. So, these are the references for you to follow. To

summarize today, we defined what a circular economy is, and how the circular economy can be applied in mining, how the circular economy differs from the linear economy, and what the benefits of the circular economy are. Lastly, we also discussed how the circular economy contributes to sustainable development. We will continue this discussion in the next class. Thank you for your patience in listening. Thank you very much.