SUSTAINABLE MINING AND GEOINFORMATION

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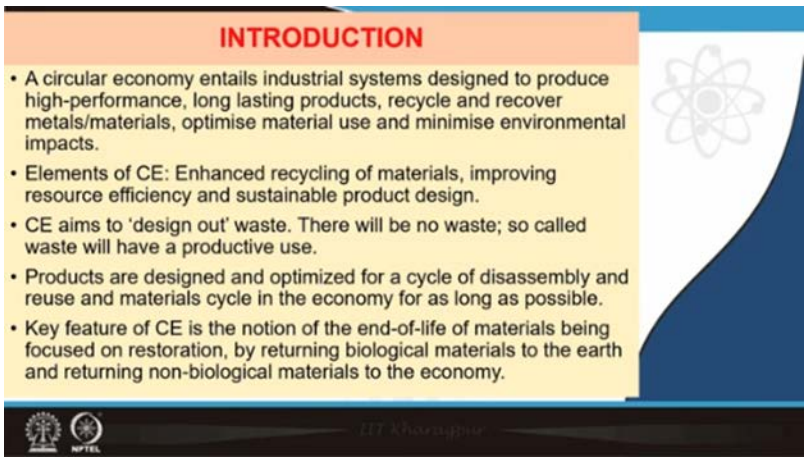
Week – 11

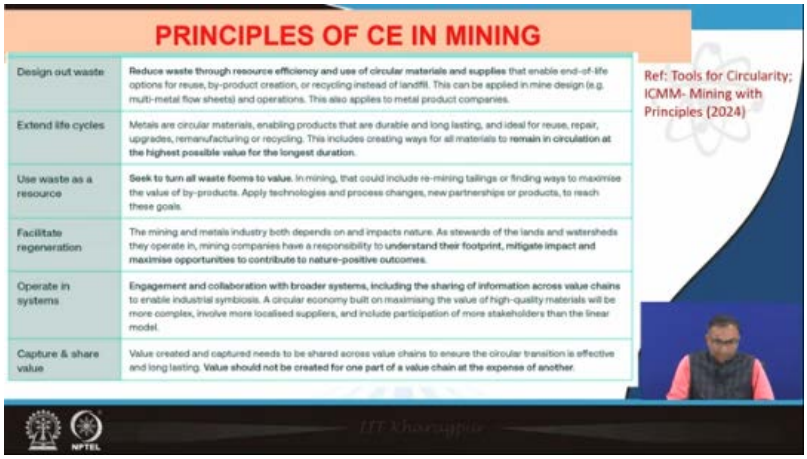
Lecture 52: Circular Economy for Mining Industry-II

Welcome, students, to our NPTEL course on Sustainable Mining and Geoinformation. Today, we are starting our lecture number 52, and the title of today's lecture is Circular Economy for the Mining Industry. In the previous class, we started the topic of circular economy, and today we are continuing that. So, in today's class, we will be covering the circular economy concept for the mining and metal industry.



We will discuss the principles of circular economy, drivers of circular economy, and then the challenges to implementing CE in the mining industry. We have discussed that a circular economy is designed to produce high-performance, long-lasting products. We can recycle and recover metals and materials, optimize material use, and minimize environmental impact. So, in the circular economy, the main components or elements are recycling of materials, improving resource recovery efficiency, and sustainable product design. So, we'll talk about—if you see this table—what are the principles of circular economy in mining? So, we'll talk about—if you see this table—what are the principles of circular economy in mining? Mainly, there are six points. These are critical to the implementation of the circular economy in mining. First is 'Design out waste.' This

document is taken from the ICMM report on circular economy in the mining sector. This document came out last year, in 2024. So, as per that document, the main element of the circular economy is 'Design out waste.' There will be no waste when we produce something in our mining system. There should not be any waste. Whatever waste we refer to—let us say overburden or tailings—we have to find some alternate uses, some productive uses for those waste materials.



So, by design, in a circular economy, there will be no waste material. For that, your resource recovery efficiency has to increase. Your waste management technology has to be developed so that the waste can be used for productive purposes. Second point: Extend the life cycle. Any product's life has to be extended by better design, better maintenance, redesign, or refurbishing. So, there are different methods by which you can extend the life of the product, particularly metals. And then, when life is over from the user's point of view, it has to be recycled. So, by these methods, the life cycles of metals can be extended. Third point: Use waste as a resource. This is very important. In mining, we produce a lot of waste—solid waste like overburden, mill tailings, and liquid waste like mine water. So, how can we use that waste material? For example, overburden can be used for filling low-lying areas or for manufacturing artificial sand, also called manufactured sand. Similarly, mine water can be used for various purposes—for agriculture, domestic use, horticulture, industrial uses, etc. Fourth point: Facilitate Regeneration. It is very important to consider how we can regenerate the value of the material. Particularly in the metal sector, it is not very difficult to imagine how we can regenerate the resource. Sixth point: Capture and share value.

So, the value that is created and captured needs to be shared across the value chains. Particularly, through research and development, we try to develop processes to use waste material as a resource. That means we are getting the value or revenue. For example, if you are able to produce manufactured sand from overburden, it can be sold in the market, creating value for the company. So, what was earlier a waste material will now add value to the company. This is the benefit of the circular economy. Now, the drivers of circularity. What are the factors that will push the transition from the linear model of the economy to the circular model? Economic value, for example. Using scientific methods of mining, our resource base is increasing through the use of science. Our recovery of the metal is increasing. Waste material is being sold as a resource material. This will add to your revenue or the profit of the mining company. We may have to invest in research for the development of technology. But when we develop those technologies, they will be used for implementing the circular economy, enhancing recovery and productivity, ultimately giving economic benefits to the company. So, that is one of the drivers. Secondly, there are regulatory and reporting requirements.

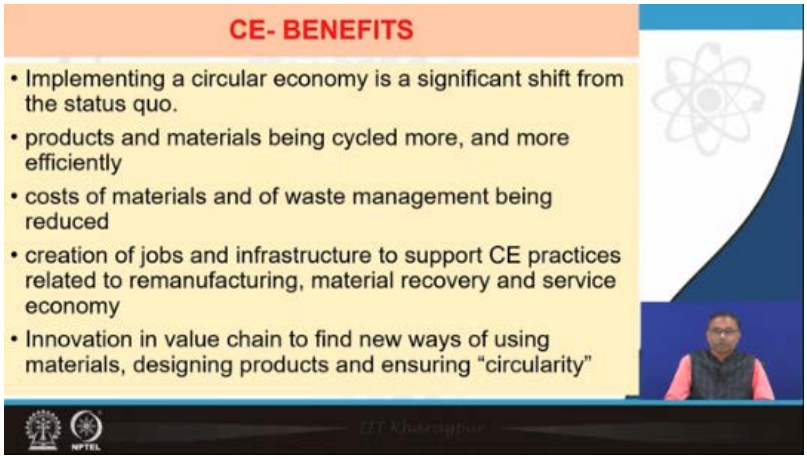
Now, there are many regulatory requirements that the company has to comply with. For example, mine closure, so all the remedial measures, reclamation measures that need to be done for the mine closure, will also contribute to the circular economy. Now that is a regulatory requirement, we have to do. If you do not do it, there will be a penalty. So, for that, we have to take all the necessary measures. So, when there is a regulatory requirement that you have to recycle your product, you have to take environmental protection measures to conserve your natural resources. So, we have to comply with. So, regulatory requirement is also a driver. Now, the regulation may not be there now, but it may come later. To comply with the sustainable development requirement, the regulation may come that it will be made mandatory. So in that case, we have to be prepared. The

mining companies have to be prepared. So that is one of the drivers of the circular economy. Stakeholder expectation. Expectation of the people, of the market, of the companies that are buying your product from. So, if they insist that you have to implement the circular economy model. The company has a good market share. For maintaining its market share, the company has to meet the expectations of consumers. So, it has to demonstrate that it is using the circular economy model. Implementing the circular economy in mining activity. Climate change. Climate change is now a very widely talked about topic, and it is implemented from the government side, from the regulator side, from the civil community, and from the environmental community. So, we have to take all measures to minimize our greenhouse gas emissions. so as to minimize our environmental footprint.

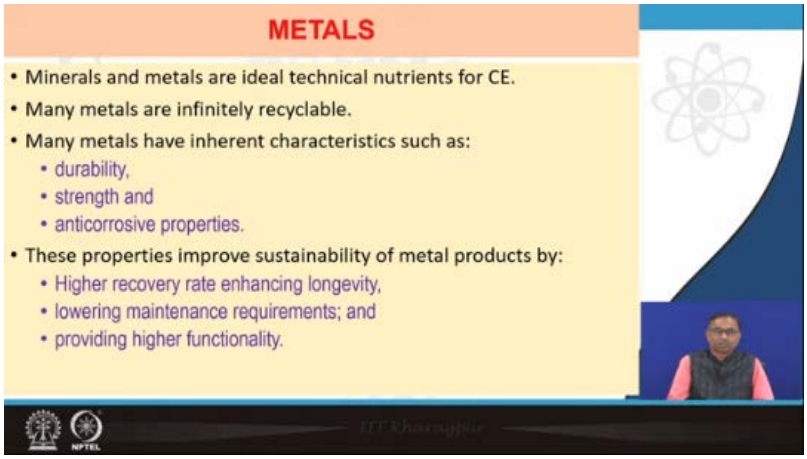
And implementing the circular economy is an important step in reducing the carbon footprint, reducing greenhouse gas emissions, as well as reducing the ecological footprint. So, climate change is also a driver. Biodiversity and natural losses. That is, we have discussed that for sustainable development, we have to preserve our biodiversity, and we take all measures, particularly in the mining industry. We have to do the afforestation, we have to create the forest cover so that when the forest cover is re-established, biological diversity will be gradually re-established also. Resource scarcity and supply security and resilience. Resource scarcity: We have discussed previously that easy-to-mine deposits are becoming exhausted. Now, most of the deposits will be deep. Most of the deposits will be in geologically difficult conditions. Now, demand for minerals is increasing. So, you have to adopt environment-friendly methods to conserve your mineral resources, so as to be able to supply the demand, so as to be able to maintain the demand, unless we conserve, we develop better technology for better resource recovery for enhancing our resource base, it will not be possible to supply whatever our mineral demand is. So, for that, implementing circular economy principles will be very, very helpful. So, the benefit of implementing a circular economy will be a significant change from the status quo, which is the linear method of the economy. Now, products and materials, when they are recycled

more and more efficiently, then the cost of material and waste management to be reduced. When you implement the circular economy, it will create jobs. It will create infrastructure for supporting the circular economy practices related to manufacturing, material recovery, recycling, and other kinds of services. So, these will create jobs for the people. Then we have to innovate in the value chain to find out ways of using

materials, recycled materials, designing products which will have a longer life, and designing products which can be recycled, so that the circular method can be implemented. Now, in terms of resources and waste, the availability of minerals and materials is critical for the economic development of the society and the country. Now, depletion of minerals, scarcity of minerals, and metals are a challenge to any society. Mineral availability and or scarcity of the minerals is linked with technology, innovation, and economic factors. By developing technology today, whatever we call a waste material, tomorrow, it will be a resource. For example, say, iron ore, earlier, less than 50% iron ore was counted as waste material because the technology was not there to recover the metal by smelting, but now the technology is available, where we can even recover metal from iron ore containing as low as 35% iron. So, when we use developed technology, our mineral resource availability will increase. In the absence of technological development, gradually our resource base will be shrinking, and there will be a scarcity of minerals and metals. So, for increasing the

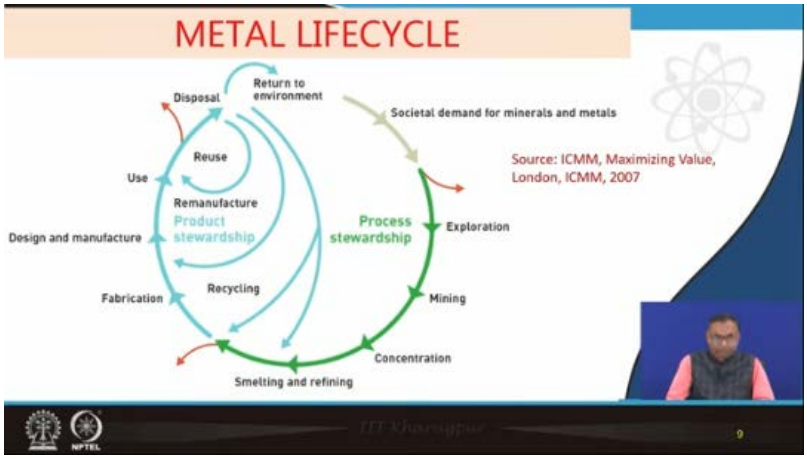


minerals availability, we have to develop technology, and we have to be innovative. Moreover, the technology that is developed has to be economical. So we have to develop economic technology. Circular economy requires exploring ways to maximize resource recovery and minimize the generation of waste. When your resource base increases, your waste material will automatically decrease. And also, we have to explore ways to enhance recycling. So, for all this, technological development is necessary, and innovation is necessary. New ways to increase our resource base, to increase our recovery, and minimize the waste generation, the means will include actions both on the upstream side as well as on the downstream side. In the mining side, upstream is in the mining sector, and downstream is in the smelter and product manufacturing sectors. So, what are the ways that we have to enhance the efficiency of the production system, both in the mining industry, as well as in the smelter, as well as in the manufacturing unit. We have to enhance the design of production. We have to design our product so that their life are long. We have to design a long-lasting product. And we have to reduce consumption. In the case of metals, minerals, metals are ideal technical nutrients for the circular economy. We have discussed biological nutrients and technical nutrients. So metals are ideal technical nutrients for circular economy because many of the metals are recyclable, infinitely recyclable because of the characteristics of the metal. For example, the durability, strength, and anti-corrosive properties, because of all these properties, the metal can be recycled again and again. These properties improve the sustainability of the metal product



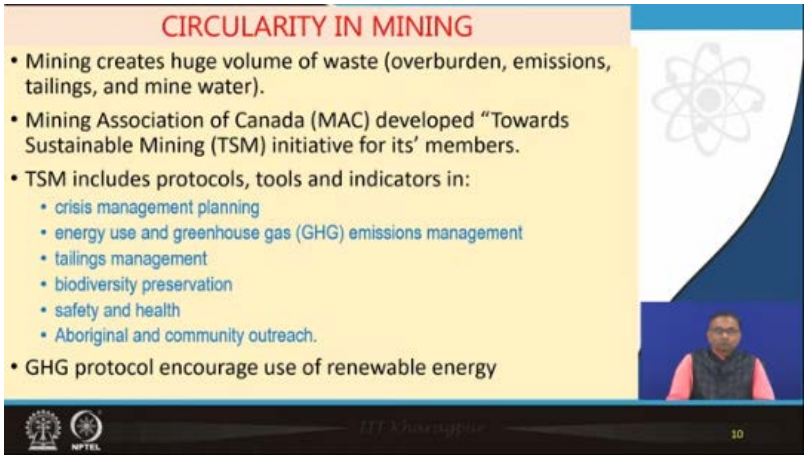
By a higher recovery rate, enhancing the longevity, lowering the maintenance requirement, and providing higher functionality. So, all these characteristics, properties of the metals make it suitable for recycling and reuse. And this will help in the circular economy, as well as in sustainable development. Now, if you look at the metal, the life

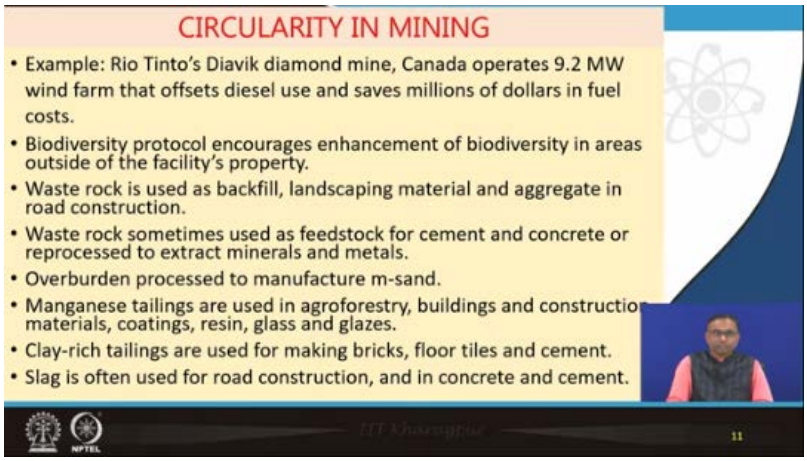
cycle of the metal, this is a diagram which we have taken from ICMM, a report of 2007. So you can see that here, for mining, it starts with the exploration, then comes the mining. From mining, it is coming to the beneficiation or concentration plant. From the concentration plant, it comes to the smelting and refining unit. And there, the metal value or the metal sheets are produced, and it is going to the fabrication unit, where different products are designed and manufactured. Here, also from fabrication, it is going to the second level of manufacturing, and then it is used by the consumer. So, it has a life cycle of its own. The product has a life, and after the useful life of the product is over, it should go to the disposal site. But in the circular economy, whatever goes to the disposal site rather than being disposed of in a landfill, is coming for reuse, remanufacture, recycling, and when it is recycled again, it is coming to the smelting. Again, it is going through smelting, fabrication, and a manufacturing unit, and again, for use. So, this is how this cycle is going on.



And ultimately, after several cycles of reuse and recycling, it can return to the environment. So this is the metal life cycle, and here in the metal life cycle, on the left side, we have reused, remanufactured, and recycled. This is very important for the circular economy in the metallic sector. Circularity in mining: Mining creates a huge volume of waste, overburden, emissions, tailings, and mine water. And the mining industry has to take initiative. So, for example, we have the Mining Association of Canada. It has developed a project called 2R Sustainable Mining. And 2R Sustainable Mining includes protocols, tools, and indicators for crisis management planning, clean energy use and greenhouse gas emission management, tailings management, biodiversity preservation, safety and health, Aboriginal and community outreach. The GHG protocol encourages the use of renewable energy. So, for example, Rio Tinto's Daibik diamond mine operates a 9.2 megawatt wind farm that offsets diesel use and saves millions of

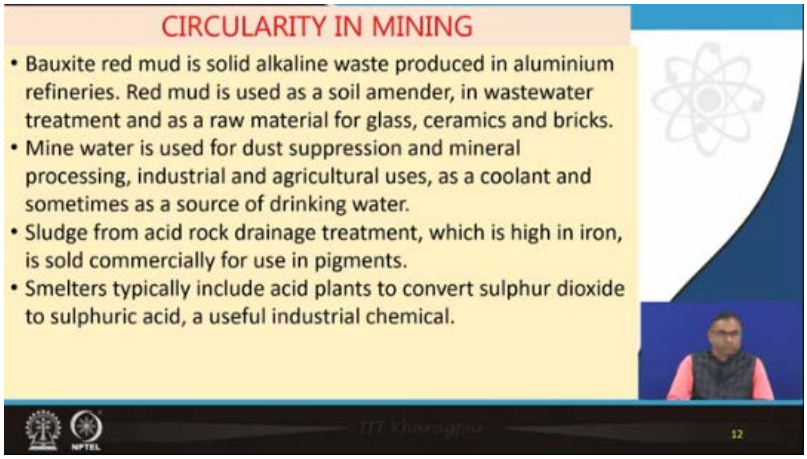
dollars in fuel bills. Biodiversity protocol encourages the enhancement of biodiversity in the mining area as well as in the areas surrounding the mining area. So, waste rock may be used as a backfill, landscaping material, or aggregate in road construction. Waste rock can sometimes be used as a feedstock for cement and concrete, and it can be reprocessed to extract waste. Minerals and metals. Overburden can be processed for manufacturing M-sand. Tailings, for example. Manganese tailings are used in agroforestry. Tailings can be used as building and construction materials, and raw materials for Coatings, Resin, Glass, and glazes, etc. Clay-rich tailings can be used for making bricks, floor tiles, and cement.

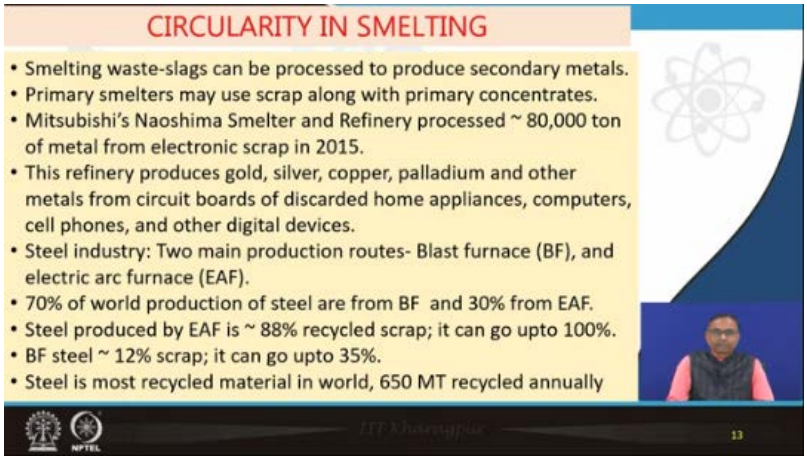




Slags from the smelting process can be used for road construction and in concrete and cement. Bauxite red mud, which is a solid alkaline waste produced in aluminium refineries, can be used as a soil amendment in water, wastewater treatment, raw material for glass, ceramics, and bricks. Mine water can be used for dust suppression. Mineral processing wastes can be used for industrial purposes, and with some treatment, they can also be used for agricultural purposes. The sludge from acid rock drainage treatment,

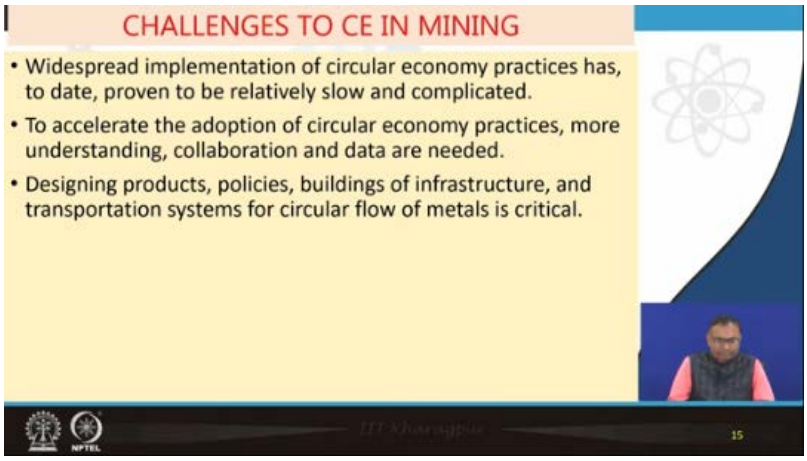
which often contains a high concentration of iron, can be sold commercially for use in pigments and smelters. Acid plants in smelters convert sulfur dioxide to sulfuric acid. This sulfuric acid can be sold in the market and can be a revenue generator for the company. Now, circularity in smelting operations: In smelter and refinery operations, smelting waste slag can be processed to produce secondary metals. Primary smelters may use scrap along with primary concentrate waste. The Mitsubishi Naoshima smelter and refinery processes 80,000 tons of metal from electronic scrap. This is a new sector developing called Urban Mining. From the scrap material that we throw into landfills, they collect and recover metals. The Mitsubishi Naoshima smelter refinery produces 80,000 tons of gold, silver, copper, palladium, and other metals from the circuit boards of discarded home appliances, personal computers, cell phones, smartphones, and other digital devices. In the steel industry, there are two main production routes through which steel is produced: blast furnace and electric arc furnace.





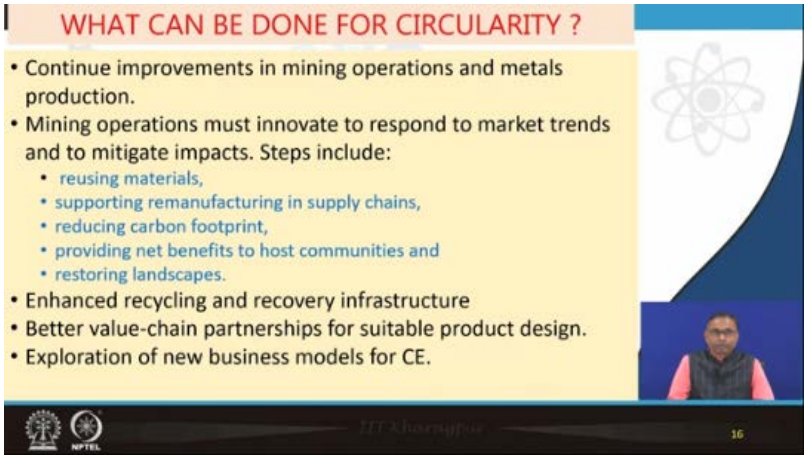
Now, 70% of the world's steel production comes from blast furnaces, and the remaining 30% comes from electric arc furnaces. In electric arc furnaces, 88% can use recycled

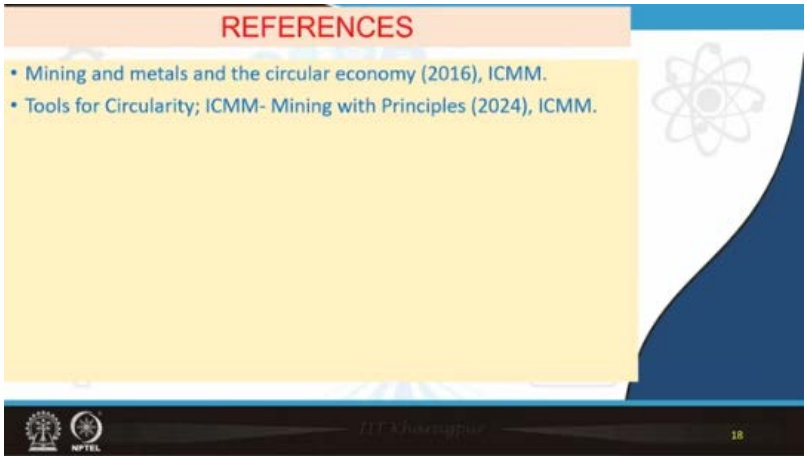
scrap, and the use of recycled scrap in electric arc furnaces can go up to 100%. In blast furnaces, roughly 12% of scrap is used, but with technological development, it can go up to 35%. Steel is the most recycled material in the world, and 650 million tons of steel are recycled annually. Circularity in smelting: Circularity can also be enhanced by increasing the recovery of co-products. For example, copper producers also recover other metals like molybdenum, gold, silver, selenium, and others. Similarly, nickel producers also recover platinum group metals, cobalt, copper, and co-products. When we recover co-products, we indirectly prevent additional mining, which helps in resource conservation as well as environmental protection. Primary smelters produce a significant share of global sulfuric acid. In smelting and beneficiation plants, a lot of sulfuric acid is produced, which can be sold as a product to the chemical industry. The off-gas cleaning process turns acidic gas emissions into a valuable product like H2SO4, and the need for additional sulfuric acid production is prevented by producing sulfuric acid from the beneficiation plant. Challenges to the circular economy in mining: Widespread implementation of circular economy practices to date has proven to be very slow and complicated. To accelerate the adoption of circular economy practices, a more critical understanding and collaboration throughout the supply chain—between miners, smelters, manufacturers, and users—is needed. Collaboration is required to implement the circular economy.



Scientific data is also very essential. The design of sustainable, long-lasting products and policies needs to be developed, and building infrastructure and transportation systems for the circular flow of metals is critical. What can be done for circularity? Mining companies must continue to improve their operations and metal production. Mining operations must innovate, respond to market trends, and mitigate impacts. Steps to adapt circularity include reusing materials, increasing reuse, and recycling. Supporting remanufacturing in the supply chain, reducing carbon footprint, providing benefits to host

communities, restoring and reclaiming landscapes, enhancing recycling and recovery infrastructure, fostering better value chain partnerships for sustainable product design, and exploring new business models in the circular economy scheme are essential for implementing the circular economy. Economic methods in mining companies. To summarize, in today's class, we discussed the circular economy concept for the mining and metals industry, principles of the circular economy, drivers of the circular economy, and the challenges of implementing it. These are the references. I prepared for the lecture using two documents: both from ICMM—one from 2016, 'Mining, Metals, and the Circular Economy,' and another, 'Tools for Circularity: ICMM, Mining with Principles,' an ICFM publication. Next class, we will continue this topic on the circular economy.





There, we will discuss how this circular economy concept can be implemented for a particular mining operation, whether it is coal mining or non-coal mining. We will take one more class on the circular economy. Thank you for your patience, and thank you.