

SUSTAINABLE MINING AND GEOINFORMATION

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Week – 11

Lecture 53: Circular Economy for Mining Industry-III

Welcome, student, to lecture no. 53, NPTEL online certification courses on Sustainable Mining and Geo-information. So, today's lecture, we will continue to discuss on implementation of circular economy in the mining industry. This is the third lecture on circular economy, and today we will talk about the implementation of circular economy in the mining industry, particularly the metal industry. We will cover the following topics in today's lecture. The circular economy concepts for the mining and metals industry: Principles and strategy to implement circular economy in the mining and metals sector; Benefits of implementing the circular economy in the mining and metals sector. So, in the introduction, we have already discussed what a circular economy is, and how it is different than the present take-make and dispose model of industrial economy. So, to give a context, that world is making several efforts to mitigate the effects of climate change. We all know that because of industrial activity, climate change is taking place because of the greenhouse gas emissions from industrial activity, and we have to take several measures to restrict global warming or mitigate the effects of climate change. There are several measures that can be taken in the economic system.



CONCEPTS COVERED

- Circular Economy Concepts for mining and metals industry
- Principles and strategy to implement CE in M&M sector
- Benefits of implementing CE in M&M Sector

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INTRODUCTION

- World is taking several efforts to mitigate climate change effects.
- Adopting circular economy is one of the major steps.
- CE involves designing out waste while products are not discarded, but looped back into the material flows.
- New approach compared to "take-make-dispose" industrial economy.
- CE model will create a disruption in current industrial economy.
- Transition to CE requires regulatory push, investment, pressure from society and change in mind-set.
- Need of R&D to design and develop product, services, and technology.

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One suggestion is that we can transition to a circular economy. This will help in reducing the consumption and thus will help in reducing the environmental impact and help in mitigating the effects of climate change. So, adopting the circular economy for the total economic system, for the total economic model of the country that we are talking about. And if you remember the previous classes, when we are using the circular economy, design out the waste, there will be no waste in the circular economy model. Whatever waste that is produced is used as a raw material or as a resource for producing some other product, which is useful to society. Like in the current approach, that is, the take-make-dispose industrial model, we produce something, and it is used. It has a particular span of life, and then it is disposed of and goes to the landfill after its productive life. The current model produces a lot of waste material in the landfill. In the circular economy, the product will not be discarded, and it will be looped back into the material flow. So, this approach is completely different than the current economic approach. So, that is why the circular economic model will create a disruption in the current industrial economy. However, the transition from the current economic model to the circular economic model will require some regulatory push. There has to be regulatory pressure that we have to break from the status quo, and it will also require investment in terms of designing new technology, designing recycling technology.

It will also require push from society, and lastly, it will require a change in the mindset to break the status quo. So, if you want to do something different, definitely the companies, the manufacturing company, including the mining company, have to welcome it with an open mind, otherwise it will not happen. So, mindset is very important. There has to be a lot of research, development, and innovation because the circular economy will involve the recycling concept. Dominantly, recycling is a critical component of the circular economy because we do not want to waste anything. So, through recycling and other

remanufacturing, maintenance, and refurbishing, the product life has to be lengthened. That is the critical component of the circular economy. So, for that, there has to be research and development, a new design, a new economic model, and new supply chains have to be created. And these will create new business opportunities, new jobs, and new disruptions. So, this is how the circular economy will be implemented, and changes will be happening. Now, if we particularly look at the mining and metal sector, particularly the metal sector. The mining and metal sector (M and M) they are a large consumer of resources. Particularly the metal industry: steel industry, aluminum industry, copper industry, it consumes a lot of raw materials, a lot of energy, and produces a lot of waste material, it emits a lot of greenhouse gases like CO₂

So, the M and M sector is a large consumer of resources and energy. The metal has a peculiar good property that it is amenable to recycling. It can be recycled again and again without losing its basic properties. This property of the metal, which is amenable to recycling again and again, makes the implementation of the circular economy in the mining and metal sector feasible. The metal sector should enthusiastically adopt the circular economic model because this is quite possible because of the favorable properties of the metals. However, the implementation of the circular economy will require structural changes in the mining supply chain. The mining economy system, the entire value chain of the mining and metals, needs to be restructured because, as we have discussed previously, mining generates a huge quantity of waste material, particularly in the metalliferous mines where the percentage concentration of the metals in the ore may be very low. It generates a lot of waste material, and in the circular economic model, this waste material they are no longer treated as waste, as it has to be converted to useful resources, it has to be converted to raw material for other industrial applications.

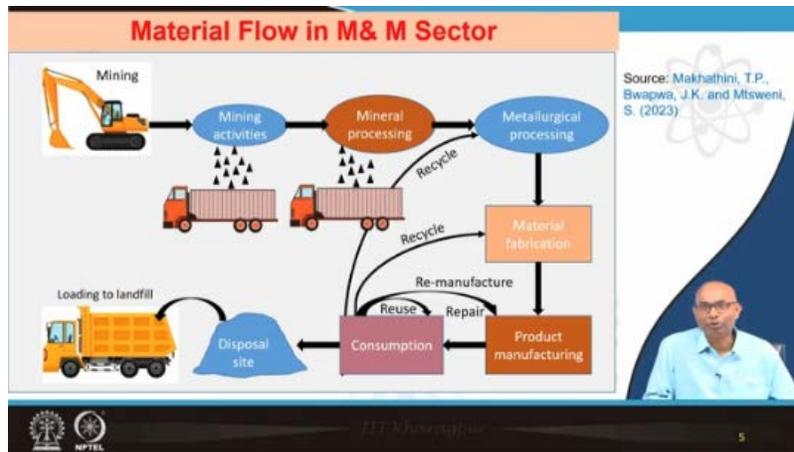
CE in Mining & Metals Sector

- M&M sector is a large consumer of resources and emitter of CO₂.
- M&M industry can take several actions to adopt to circular economy and implement circularity.
- Implementing CE will cause structural changes in the mining supply chain and economic system.
- The entire value chains of mining need to be restructured.
- Mining waste will be converted to valuable resources.
- Valorise huge quantity of mine waste into resources will be a challenge.
- CE will generate new sources of revenue for the M&M sector
- Create new business opportunities and disrupt existing business models.

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So, mining waste will be converted into raw material for other industrial applications. So, this will require a lot of R&D effort. It will require the creation of a lot of facilities, a manufacturing facility that will use the mining waste as a raw material. It will require a lot of investment. To valorize a huge quantity of mine waste into a resource, it will be a big challenge. It is not going to be easy. So, today we think that we want to use our overburden material. We want to use the mill tailing, mine tailing as a raw material. It will not happen like that. You have to develop suitable technology, you have to modify it, and you have to process the waste material, so that different types of products can be developed out of that. So, it will be a huge challenge. However, if we can develop this processing technology, in which the waste material will be used as a raw material or as a resource to produce some useful product. Then we can generate a lot of revenue because this waste material is used as raw material for some other industry. So, we can sell the so-called mining waste material to industry, and it will generate a lot of revenue for the mining and metal sector. So, that is why it will create new business opportunities because there will be a disruption in the existing business model.

There will be the creation of new business opportunities and new employment opportunities. This will be a win-win situation if we implement the circular economic model in the mining and metal sector, although it will require initial investment and development of technology. But once we develop that critical technology, then it will be a revenue earner for the mining company. It will be a win-win situation for the mining companies. You can see the present mining model, what is the material flow in the mining and metal sector? So, you can see that you are using heavy earth-moving equipment in the mining and production of the raw material. Minerals which is going to the mineral processing unit, where value enhancement takes place, the grade is improved, waste is produced, and then the improved ores go to the metallurgical processing industry, like smelters, steel plants, and then you are producing the metals. So, these metals are going to the material fabrication unit in the manufacturing plants, and they are going to the specific product manufacturing plants where finished products are manufactured. The finished product is going to the market for consumption. It could be an industrial product, it could be a domestic product, but it is going to the market for consumption. Once the life of the product, the productive life of the product, is over, then what are we doing? We are disposing of the product, the exhausted product, and the defunct product.



And then from the disposal site, it is going to the landfill, where ultimately the waste material from the manufacturing unit, from the consumption locations (domestic or industrial), comes to the disposal site, and then it is going to the landfill, where it is ultimately disposed of. So, you can see in the disposal site, there will be environmental impact, but now, if we want to implement the circular economy model, then at every stage, particularly product manufacturing and consumption. So, they are using recycling, remanufacturing, and reuse by using a maintenance protocol. So, the raw material can come to the metallurgical processing unit for recycling, then the product can come to the material fabrication unit for recycling, and the product can come to the re-manufacturing facility for remanufacturing. So, using all this recycling, remanufacturing, reuse, maintenance, and repair, what are we doing? We are enhancing the life of the product, and ultimately, when the productive life is over, it will come again to the metallurgical plant, where again, it will be melted and the metals will be produced. So, there is no concept of waste because all wastes are used. So, this is the material flow. Now, critical principles for circular economy in the M and M sector, there are three critical principles that are used for the circular economy. One is to prioritize the renewable input. So, renewable input includes renewable energy.

In the circular economic model, we will use renewable energy and all renewable input materials. The second principle is to maximize product use. So, a product has a life and will extend its life through different technologies. So, product utility will be maximized. And because our product life is increasing, product utility and product use are increasing, so our resource demand will also decrease. And thirdly, we are recovering by-products. We are recovering by-products and using the waste as a resource, waste as a product. Because the waste is used as a resource, the environmental impact will be less because waste will be less, and we are recovering byproducts. Further, as we are using waste as a

resource, so, our revenue will be more. Profit will be more. Profitability will be higher. So, these are the three principles. Renewable input, including renewable energy, maximizes product use by suitable product design, develops recycling, reuse, and remanufacturing technology, then recovers by-products, co-products, and uses waste as a resource. So, these are the three core principles of the circular economy. Now, how are we doing that? Principle one is the use of renewable input. It can be achieved through circular sourcing. Circular sourcing: In this concept, there is no waste material. So, whatever raw material, it is regenerated. So, metals fit the bill very aptly.

Critical Principles for Circularity in M&M Sector

Prioritise Renewable Input Maximise product use Recover by-products and waste

Source: The rise of circularity- How the GCC is transforming from the inside for the outside - Metals and Mining, PWC, 2021.

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Critical Principles for Circularity

1. Use of Renewable inputs.
Can be achieved through circular sourcing, use of renewable energy, sustainable design of product and production line, and by optimising resource efficiency;

2. Maximise lifespan of products and extract highest possible value.
products are reused, product uses and functions are optimised, and sharing is encouraged;

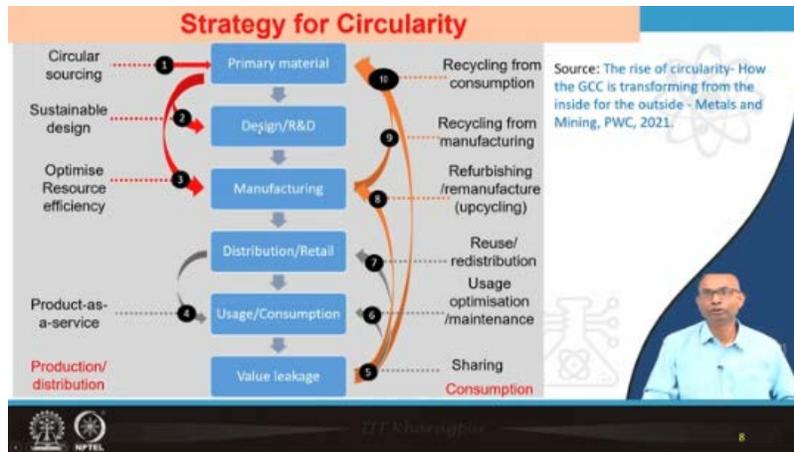
3. Recover by-products and waste.
Involves refurbishing, remanufacturing of product at end of its life, recycling back into production line and reusing the by-products of manufacturing.

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Use of renewable energy, sustainable design of products and production lines, and optimization of resource efficiency. So, using renewability, renewable input, we have to design for longer life, sustainable design, which can be recycled again and again. In the metal industry, because of the favorable properties of the metal, it can be done through research and development, and it can be developed. Maximize the lifespan of the products and extract the highest possible value. So, when you maximize the lifespan of the product, your product life increases. Because of the recycling, you are extracting the

maximum value from the raw material. Products are reused, and product uses and functions are optimized. Product sharing: There may be several users of a product. So we share that product among the different users. For example, you have a car. So, we take the car to go from one place to another, or from the workplace to the residence, and from the residence to the workplace. You know the concept of carpooling. So, in the carpooling, if I have a car, I drive it, and then I invite people, maybe two or three of my friends who are going from the same location to my office. So, instead of four people driving the car, we share the car. So, this is an example of a sharing of resources. So, in the case of mining, for example, we have machinery. So, this machinery can be shared between two or three mines in the same locality.

The machinery is sometimes used for mine A, and then it can be used for mine B. So, the mine does not have to purchase it for exclusive use, and the machine can be shared between the mines. But, for this optimization to be done. The optimisation models are possible and can be applied to the machinery used by several mines. Recovery of by-product and waste: it will involve refurbishing, remanufacturing a product at the end of its life cycle, recycling back into the production line, and reusing the by-product of the manufacturing plant and the waste material of the waste product after its life. So, waste from the manufacturing plant, waste material from the smelter we will be using, and when the product life is over, it will go back for refurbishing and remanufacturing. So, these are the three core principles, and to implement these three principles, there are ten strategies for circularity. So, the first one is circular sourcing, then circular design. So, this has to be in the design lab for R&D. We have to undertake R&D efforts for the sustainable design. Then, with the sustainable design, it will go to the manufacturing plant where a sustainable product will be manufactured, and any waste material will also be used as a resource, or it will go back to the manufacturing plant. Then the product is manufactured in the manufacturing plant, and it is going for distribution, to the retail, or it is going to the consumption, for usage. Any value leakage, after the productive life of the product is over, will be treated as a leakage; it is not treated as a waste material, but it will be treated as a leakage, and this leakage will go through maintenance. After the maintenance, it will be reused, redistributed.



Then, if there is any loss of property, it will be again refurbished, remanufactured. Then, from the manufacturing plant, the waste material will be recycled in the manufacturing process, and then from the consumption, the final waste material will be added to the primary material. Along with the primary material, it will come to the metallurgical unit where the metal will be produced, new metal will be produced, and a new product can be developed. So, these are the 10 different strategies for circularity we will discuss one by one. So, first is circular sourcing. So, replace finite resources or materials with renewable, bio-based, or recycled materials in the production process. So, for the metal industry, there is bio-based, renewable energy and raw materials. So, the metallurgical industry should have developed the technology that it can use the recycled material from the end of the life of the product, which again comes mixed with the new material, so that the new metal can be developed in the metal smelter, and it will require a sustainable design of the product. Select raw materials such that they can be effectively disassembled, reused, repaired, and off-cycled. So, the waste material from the plant has to be off-cycled, so that it can again work as a new raw material. So, the value is added there, which is called off-cycling.

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- Strategy for Circularity in M&M Sector**
1. **Circular sourcing:** Replace finite resources/materials with renewable, bio-based or recycled materials in the production process.
 2. **Sustainable design:** Design products and select raw materials such that they can be effectively disassembled, reused, repaired and up-cycled.
 3. **Optimising resource efficiency:** Optimise usage of raw materials, resources, minimise waste in the production process.
 4. **Product-as-a-service:** Provide a service in areas that were traditionally sold as products; increases the product lifecycle through repurposing at the end of usage
 5. **Sharing:** Share durable assets such as cars, rooms, appliances and digitise products to increase their lifetime (e.g. vessel pooling amongst operators, technologies to reduce field movements etc.)

Optimizing resource efficiency, optimum use of raw materials, and minimizing waste in the production process. So, when we are doing the sustainable design, automatically our resource efficiency will increase, and our consumption of raw materials will decrease. Fourth strategy, product as a service. For example, in mining, we are using a lot of machinery, such as a dragline, shovel, dumper. The mining company purchases the machinery, and it is the exclusive user. Now, instead of that, the mining company can make a contract with the machinery company to lease the equipment. So, product as a service. So, the machinery company will provide the loading and unloading services. So, whenever any degradation takes place in the equipment, the machinery company can take it and will maintain it, it will refurbish, it will remanufacture it, so that is, the machinery producer provide a service in the areas that were traditionally sold as product and by this approach the product life can be increased by repurposing at the end of the usage. Sharing of resources, such as sharing cars, rooms, appliances, so our mining machinery or any smelter can be shared. So, the smelter can get raw material from several plants and provide the steel to several plants, so that the optimum use of the plant takes place. So, this model we can use with the mining machinery also. Machinery usage optimization and maintenance: Any product we have to improve the maintenance facility. So, through improved maintenance technology, the product life can be prolonged.

Then, after the maintenance, the same product can be reused and distributed to the various companies. Purchase and sell second-hand and previously owned products to increase product life, refurbish or remanufacture product components for new usage rather than down-cycling. Down-cycling means we are using that for an inferior use, but we develop improved remanufacturing, refurbishing, taking so that the product will be used for the same purpose, same value purpose. Recycling from the manufacturing plant and recycling from the consumption unit. So, recycling is very, very important in the implementation of the circular economy, particularly in the mining and metal sector. Recycling enables the creation of new goods with a far smaller carbon footprint and also a far smaller amount of essential raw materials. So, the demand for virgin resources will decrease if you use recycling extensively. Now, metals are circular by nature and can be recycled indefinitely without losing their basic properties. However, when we are designing the product, the design modification is essential so that the products can be recycled, remanufactured, and refurbished. So, it will require design modification. And if we do the recycling, it will reduce the consumption of primary minerals, and it will reduce the demand for primary minerals at the mine level as well as at the national level. But you have to remember that even if we recycle 100 percent of the minerals and metals,

this will not be sufficient to fulfill our future material needs because of our growing economy.



Recycling

- Recycling enables the creation of new goods with a far smaller carbon footprint than by extracting virgin resources;
- Metals are circular by nature, and can be recycled indefinitely without losing their properties.
- Design Modification important for recycling.
- Recycling will reduce the consumption/ demand of primary minerals.
- Even if we recycle 100% of the minerals and metals extracted, this would not be sufficient to fulfill future material need.
- Mining of new ores still necessary to meet demand of the economy.

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Our raw material and metal demand are increasing. So, even if we recycle 100 percent, we still have to mine virgin ores. New ore bodies are still required to be mined. So, the benefits of recycling are increasing resource efficiency by reducing consumption, reducing waste production, reducing accumulation of waste, enhancing innovation, and the growth of local industry. Because recycling will require a lot of innovation, the development of a business ecosystem where maintenance, new products will be designed and manufactured. It will create employment opportunities through small businesses and entrepreneurship, and shared responsibility for environmental affairs. So, if you look at the waste material in the M&M sector, mines, and metal sector, particularly from mines, we are producing overburden rock, mine tailings, and wastewater. And in the metallurgical industry, we are producing metallurgical waste like slags and other byproducts. Now, how will these waste materials from the mines and the metallurgical plant be used as a resource? We have to find different productive uses of these waste materials so that these wastes are not just disposed of and create environmental pollution. Particularly in mining, the overburden rock can be used as a construction material. We can use overburden and produce manufactured sand or m-sand. M-sand is a critical construction material for building houses and other things; it can be used as a filling material in the low-lying areas. Overburden can be used for filling, for the construction of roads, road-making material, or backfilling of mines. Mine tailings can be used as construction material for making hollow block bricks, tiles, RCC roller compacted concrete, geopolymer, and also as the backfill of underground mines.

Benefits of Recycling

Source: Makhathini, T.P., Bwapwa, J.K. and Msweni, S. (2023)

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M&M Sector Wastes

- **Overburden rocks, mine tailings, wastewater, metallurgical waste** and other by-products.
- **Overburden rocks** can be used as construction material, m-sand, filling materials, road making, back filling of mines etc.
- **Mine tailings** can be used as construction materials for making hollow blocks, bricks, tiles, roller compacted concrete (RCC), geopolymers, backfilling of mines etc.
- Secondary mining from mine tailings.
- **Mine Wastewater** can be treated and used for several purposes including industrial uses.
- **Secondary metal recovery** from metallurgical wastes

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From mine tailings, we can do secondary mining to produce valuable minerals and metals because the metalliferous ores contain a lot of other associated metals and minerals. Mine wastewater can be treated and it can be used for several purposes, including industrial uses, and for horticulture purposes. Even some of the water after treatment can be used for agricultural purposes, depending on the quality of the water from metallurgical waste. Secondary metal recovery is possible, provided we develop the extraction technology through suitable R&D. So, the benefits of the circular economy in the mining and metal sector are better utilization of resources, enhancing the life of the resource base, lowering the environmental life cycle impact, creating new service providers, a business ecosystem, and local jobs. Nationally, the circular economy can reduce the import of raw materials. Waste is used as assets, and when waste is used as assets, it will create a new industry. It will create job opportunities. Then, when we are implementing the circular economy, it will improve, enhance the reputation of the mining company, and improve its ESG rating. ESG is environment, society, and governance. By implementing the circular economy, they can enhance the ESG rating. And nowadays,

ESG rating is very, very important. It has become mandatory for all corporations. And when your ESG rating improves, you can get funds, loans at a reduced interest rate. So, to summarize, we discussed the circular economy concept of the mining and metal sector.

Benefits of CE in M&M Sector

- Better utilization of resources; enhances life of resource base.
- Lower environmental life cycle impact.
- Create new service providers, business eco-system and local jobs.
- Nationally, CE can reduce imports of raw material,
- Waste used as assets; creates new industry and jobs.
- Improves reputation of mining company
- Can improve ESG rating of the company.

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We discussed principles and strategies to implement a circular economy in the mining and metal sector, the importance of recycling, and the benefits of recycling in mining, as well as the overall benefits of a circular economy in the M&M sector. These are the references I have followed, and with this, our lecture on Circular Economy and its implementation in the mining sector is complete for this class. I have taken three classes to discuss the circular economy. This is a very important topic, so it should generate some interest to learn about it. I hope you have developed an understanding by now of what a circular economy is. Thank you very much.

SUMMARY

- Circular Economy Concepts for mining and metals industry
- Principles and strategy to implement CE in M&M sector
- Importance of recycling in mining
- Benefits of CE in M&M sector

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