

SUSTAINABLE MINING AND GEOINFORMATION

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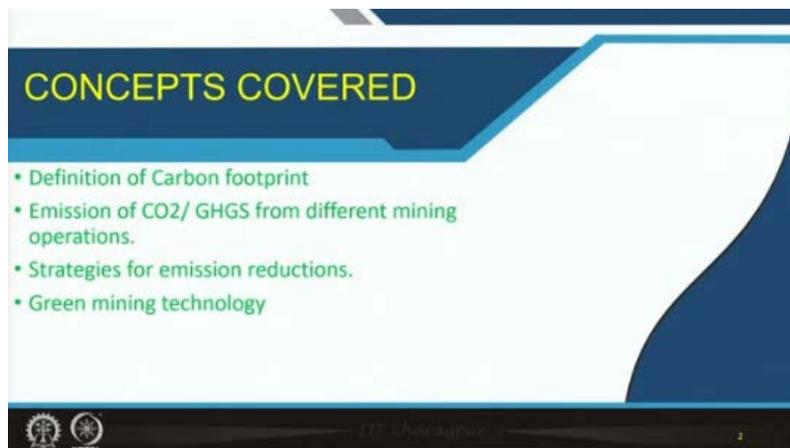
Department of Mining Engineering

Indian Institute of Technology Kharagpur

Week – 11

Lecture 54: Carbon footprints of mining industry

Welcome, students, to our lecture on the NPTEL certification course on sustainable mining and geoinformation. Today is Lecture 54. Today's topic is the carbon footprint of the mining industry. In this class, we will define what a carbon footprint is, and then we will discuss emissions of CO₂ and other greenhouse gases from different mining operations. Then we will talk about strategies for emission reductions from the mining industry, and at the end, we will talk about green mining technology and summarize. So, the carbon footprint is a very popular word or phrase that is used. We all understand the importance of carbon dioxide, which is one of the most abundant greenhouse gases, and CO₂ and other greenhouse gases are responsible for global climate change. Because of global climate change or global warming, the average temperature of the Earth, the air temperature on the Earth's surface, is increasing.



Carbon Footprint

- Carbon footprint is a measure of total amount of CO₂ emissions caused directly and indirectly by an activity (Wiedmann and Minx, 2008)
- Total of all **greenhouse gas emissions** (CO₂, CH₄, N₂O,) produced directly or indirectly due to a process is referred to as the carbon footprint.
- Carbon footprint is expressed as **Carbon dioxide equivalent** (CO₂e).
- CO₂e is calculated by multiplying the mass of a specific greenhouse gas by its global warming potential (1 for CO₂, 30 for CH₄, 273 for N₂O).
- Coal mines are one of the largest sources of anthropogenic methane emissions.
- ~33% of anthropogenic methane emissions occur during extraction and transportation of coal.
- US Environmental Protection Agency predicted that by 2030, global methane emissions from coal mines around the world will exceed 784.3 MtCO₂e.




And because of this increase in the global average surface or air temperature, there are a lot of ecological consequences happening, whether it is extreme climate events, droughts, floods, cyclones, and consequences on agriculture and food security, and consequences on the ecosystem. Many changes are taking place. Because of this, the IPCC, the Intergovernmental Panel on Climate Change, has organized many conferences; you might know about the Paris Agreement. As per the Paris Agreement, we have to restrict the global temperature rise to 2 degrees Celsius. Many countries across the world have agreed to take initiatives and measures to reduce greenhouse gas emissions to the atmosphere, mostly the emission of CO₂, so that the average air temperature increase is restricted to 2 degrees Celsius. We should all strive to restrict it to 1.5 degrees Celsius. So, 2 degrees is the commitment, but extra initiatives will be taken to restrict the global air temperature increase to 1.5 degrees Celsius. This is the importance of CO₂ emissions, anthropogenic CO₂ emissions.

Now, CO₂ emissions are taking place from various industries: fossil fuel power plants, steel industry, cement industry, coal mines, etc. From many industries, carbon emissions, or carbon dioxide emissions, which we call carbon emissions, refer to the total amount of CO₂ emissions caused by an activity directly or indirectly. That is the definition of a carbon footprint. But broadly, it is not only about CO₂ emissions; it is the total of all greenhouse gas emissions produced directly or indirectly from a specific process or industry, which is known as the carbon footprint. When we talk about greenhouse gases, the prominent greenhouse gases are carbon dioxide, methane, N₂O, water vapor, and fluorinated gases (CFC, HFC, etc.). They are considered important greenhouse gases. Each of these greenhouse gases has a global warming potential. CO₂ is taken as the reference, and the global warming potential of CO₂ is one; for methane, it varies between 23 to 30. For nitrous oxide, it is 273. So, the carbon footprint is expressed as carbon

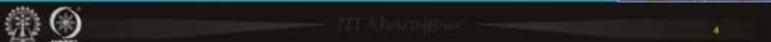
dioxide equivalent because, from a process, carbon dioxide and other greenhouse gases are emitted, and we have to measure the mass of each of the specific greenhouse gases.

And we have to multiply the global warming potential of specific greenhouse gases by the mass of the specific greenhouse gases; that will give the carbon dioxide equivalent. So, that is how we calculate the carbon footprint. So, the mining industry is also contributing to greenhouse gas emissions. We know that coal mines are one of the largest sources of anthropogenic methane emissions, and not only methane but also CO₂ is emitted from mines. In the mines, we have so many unit operations, where we are using electricity, we are using a lot of heavy earth-moving machinery/ equipment which are running on diesel. So, combustion of diesel is taking place. CO₂ and oxides of nitrogen and other gases are also emitted during those operations, and they contribute to the carbon footprint from the mines. So, 33% of anthropogenic methane emissions occur during the extraction and transportation of coal. The US Environmental Protection Agency predicted that by 2030, the global methane emissions from coal mines around the world will exceed 784.3 million tons of carbon dioxide equivalent.

The Intergovernmental Panel on Climate Change, IPCC, brings out scientific reports about the emissions of greenhouse gases from various countries and various sectors. As per the IPCC reports, the anthropogenic global greenhouse gas emissions between 1970 and 2020 has been increasing significantly annually by 7.8 percent, and in the anthropogenic greenhouse gases, CO₂ is contributing 76 % by weight, methane is contributing 16 % by weight, nitrous oxide is contributing 6% by weight, and fluorinated gases contribute 2% by weight. The International Energy Agency (IEA) calculated that 75 percent of anthropogenic CO₂ emissions come from the power plants that are burning fossil fuels like coal, petroleum, and natural gas. Between 1975 and 2018, the atmospheric CO₂ level increased from 250 ppm to 410 ppm. So, looking at the emissions of greenhouse gases from anthropogenic sources and also looking at the concentration of the various greenhouse gases in the atmosphere, and knowing that carbon dioxide is the dominant greenhouse gas, which is contributing to climate change and global warming.

Global Carbon Footprint

- Intergovernmental Panel on Climate Change (IPCC): Anthropogenic global GHG emission between 1970 and 2020 has been increasing annually by 7.8%.
- Anthropogenic GHG: CO₂ (76 %), CH₄ (16 %), N₂O (6 %), fluorinated gases (2 %) (all weight %).
- International Energy Agency (IEA) calculated that ~75 wt% of anthropogenic CO₂ is emitted because of the burning of fossil fuels.
- Carbon dioxide is the main GHG responsible for global climate change.
- Between 1975 and 2018, atmospheric CO₂ levels increased from 250 ppm to 410 ppm.
- Paris Agreement: Anthropogenic Carbon dioxide emission has to be minimised to limit the global average temperature increase to 2 deg C and effort to be made to limit the temperature by 1.5 deg C.

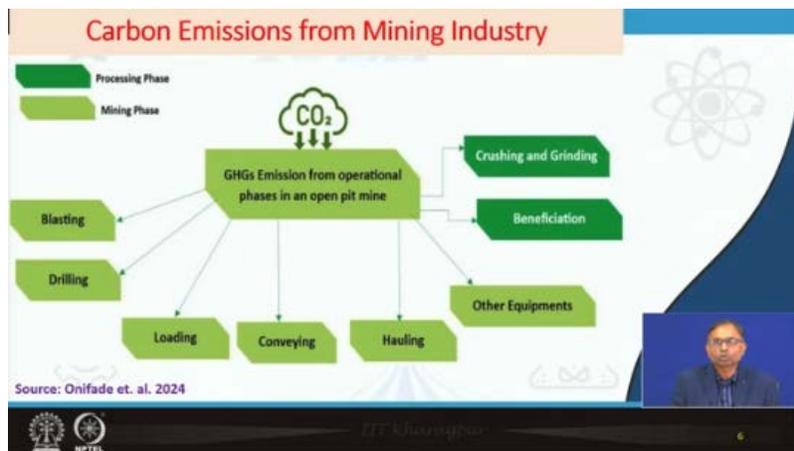
So, as per the Paris Agreement, the anthropogenic carbon dioxide emission has to be minimized to limit the global average temperature increase by 2 degrees centigrade, and this is a commitment that the carbon dioxide emission has to be minimized. So that the average global temperature increase is restricted to 2 degrees centigrade. But all efforts must be taken by the signatory countries so as to limit the temperature by 1.5 degrees Celsius. 2 degrees is a commitment, and 1.5 degrees centigrade is the all effort to be taken by the signatory countries. India is a signatory to this Paris Agreement. India has committed to net-zero carbon emissions by 2070. And if you look at the statistics, India is the second-largest developing economy globally. And in recent times, in the last decade or so, starting from the 90s, India has been developing significantly. So, India is also consuming a lot of energy, keeping pace with economic growth. Most of our energy consumption and production is coming from the fossil fuel facilities. So, our CO₂ emissions have also proliferated in the past decades. India emitted about 17.54 million tons of CO₂, which contributed to 7.2% of the world's total CO₂ emissions in the year 2020.

Carbon Footprint of India

- India has committed to net-zero carbon emissions by 2070.
- As the second-largest developing economy globally, India's CO₂ emissions have proliferated in the past decades.
- India emitted ~ 17.54 Mt CO₂, which contributed 7.2% of the world's total CO₂ emissions in 2020.
- Coal-fired electricity generation accounted for 72% of India's electricity generation in 2020.
- IEA projected that India's electricity demand is expected to rise due to the growth of air-conditioning appliances in the coming decades.
- With rise in electricity demand, CO₂ emission is set to increase.




Coal-fired electricity generation accounted for 72% of India's electricity generation in 2020. The IEA projected that India's electricity demand is expected to rise due to the growth of air conditioning appliances in the coming decades. Our economy is also growing at a rate of 6 to 7 percent per year. So, keeping pace with our economic growth, our electricity demand will also increase, and most of the demand will come from the increased use of air conditioning appliances. With the rise in electricity demand, CO₂ emissions from India are also set to increase. The mining sector is one of the main contributors to CO₂ emissions and also to emissions of other greenhouse gases, particularly methane. The mining sector, particularly the coal mining sector, emits a lot of methane. So, we will see how the mining sector emits greenhouse gases. Here is a diagram you can see, where mining is divided into different unit operations. First, it is divided into two phases: the mining phase and the beneficiation or processing phase. In the mining phase, we have several unit operations: blasting, drilling, loading, conveying, hauling, and the use of heavy equipment for different purposes like crushing, grinding, and transportation.



Then, in the mineral beneficiation plant, you have crushing, grinding, and other beneficiation processes. These are the different unit operations of the mining and beneficiation phases, and there will be emissions from each of these processes. So, in each of these processes, we are either using different equipment that runs on electricity. When the machines run on electricity, the electricity in most cases comes from fossil fuel-based sources. So, there will be indirect emissions. Indirect emissions of CO₂, nitrous oxides, and water vapor are produced from electricity facilities. We use electricity or different heavy earth-moving machinery or equipment that runs on fossil fuels such as diesel, and when this diesel burns in the heavy earth-moving equipment, it produces CO₂, NO_x, methane, etc. So, they also generate a lot of greenhouse gases. Altogether, when

you calculate CO₂ generation, whether it is direct in the case of using heavy earth-moving machinery where combustion takes place, or whether it is indirect CO₂ emission where you use electricity produced at a different location, the electricity may be generated from fossil fuels. So, at the site of electricity generation, there will be CO₂, NO_x, and other emissions.

When we use electricity, there will be indirect emissions. So, the direct emissions of greenhouse gases and indirect emissions of greenhouse gases must be calculated for each of these processes, and then we can add them together. When we add them together, it will give the total greenhouse gas emissions from the mining operations. We will discuss each process. Drilling, as you know, is one of the important unit operations in mining. When you have to fragment the rock, whether it is the overburden or the ore body, like a coal deposit, we have to do drilling. Drilling is carried out by large-sized drilling rigs. These drilling rigs either run on electricity or diesel power. When you use diesel-powered drilling rigs, the combustion of diesel fuel in the rigs will result in emissions of CO₂, methane, and nitrous oxide. These are direct emissions. If your drilling rig runs on electricity, then the electricity used will produce indirect greenhouse gas emissions. Blasting: We know that after drilling, we load the drilling holes with explosives and then proceed with blasting. Blasting involves the use of explosives such as ammonium nitrate fuel oil and foam to fragment rock and ore bodies. After blasting, because of the explosion, it will release a lot of blast fumes.

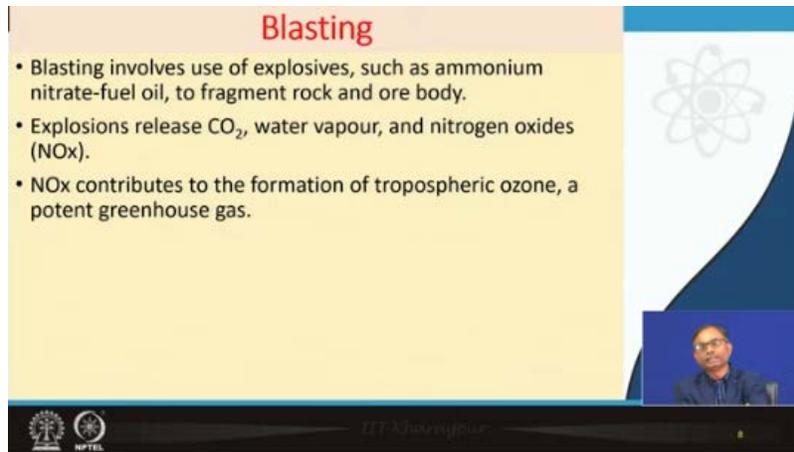
Drilling

- Drilling is one of the unit operations of mining, involving use of diesel-powered drill rigs.
- Combustion of diesel fuel in these rigs results in emission of CO₂, methane (CH₄), and nitrous oxide (N₂O).

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Blasting

- Blasting involves use of explosives, such as ammonium nitrate-fuel oil, to fragment rock and ore body.
- Explosions release CO₂, water vapour, and nitrogen oxides (NO_x).
- NO_x contributes to the formation of tropospheric ozone, a potent greenhouse gas.

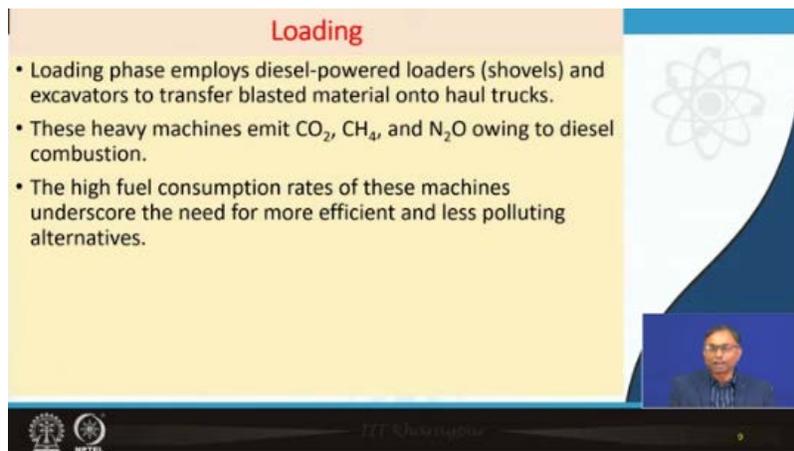


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The blast fumes mostly consist of CO₂, water vapor, and nitrogen oxides. The CO₂ and water vapor are direct greenhouse gases, or some part of the nitrous oxide, like nitrous oxide. They are part of the greenhouse gases. Now, water vapor is also one of the most important greenhouse gases. So, apart from the emissions of greenhouse gases, the NO_x also contributes to the formation of tropospheric ozone, which is a potent greenhouse gas. Next, after the blasting, when the rock is fragmented, the fragmented rock or fragmented ore will be loaded by equipment into a haul truck. We mostly use a shovel. The loading phase employs diesel-powered loaders or shovels, and excavators to transport blasted materials onto the dumpers or haul trucks. The diesel-powered shovels emit CO₂, CH₄, and N₂O, owing to the diesel combustion. Now, the high fuel consumption rates of these machines underscore the need for more efficient and less polluting alternatives. So, a lot of greenhouse gas emissions are taking place in the loading phase also. Then we are using a lot of equipment for transport and other operations.

Loading

- Loading phase employs diesel-powered loaders (shovels) and excavators to transfer blasted material onto haul trucks.
- These heavy machines emit CO₂, CH₄, and N₂O owing to diesel combustion.
- The high fuel consumption rates of these machines underscore the need for more efficient and less polluting alternatives.



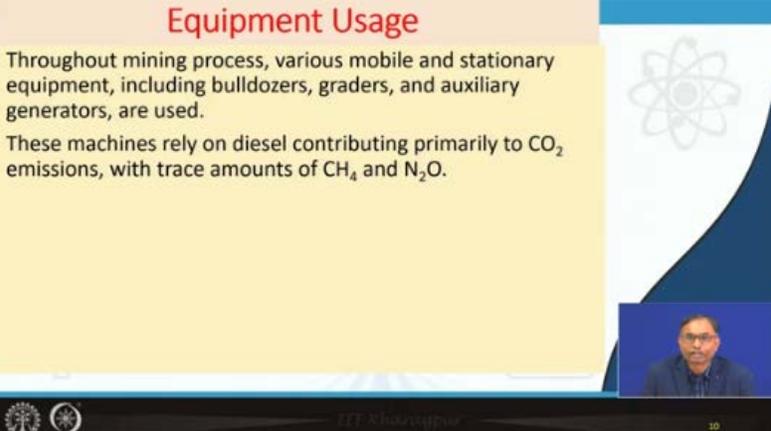
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So, throughout the mining processes, various mobile and stationary equipment are operated, for example, bulldozers, graders, auxiliary generators. Now, for transportation,

the dumpers are operated, so they are also running on diesel. So, they also generate a lot of CO₂, methane, N₂O, and other greenhouse gases. Conveying systems that transport ore and waste rock are typically powered by electricity. In countries like India, electricity is generally generated from fossil fuels, and when electricity is produced in the power plant, it emits CO₂ and other greenhouse gases. So, when we are using electricity, it is an indirect CO₂ and other greenhouse gas emissions. Now, when we are using fossil fuel energy, fossil fuel burning to produce electricity, a lot of CO₂ emissions are taking place. So, these CO₂ and other greenhouse gas emissions can be minimized if we transition to renewable energy sources. So, renewable energy sources, if used for powering the conveyor belt, can significantly reduce the carbon footprint. Now, renewable energy sources will include the application of solar energy, wind, and other types of renewable sources. Haulage: haul trucks, which transport materials from the mine to the beneficiation plant, to the processing facilities, are among the largest consumers of diesel in mining operations. The dump trucks emit a substantial amount of CO₂, methane, and nitrous oxide.

Equipment Usage

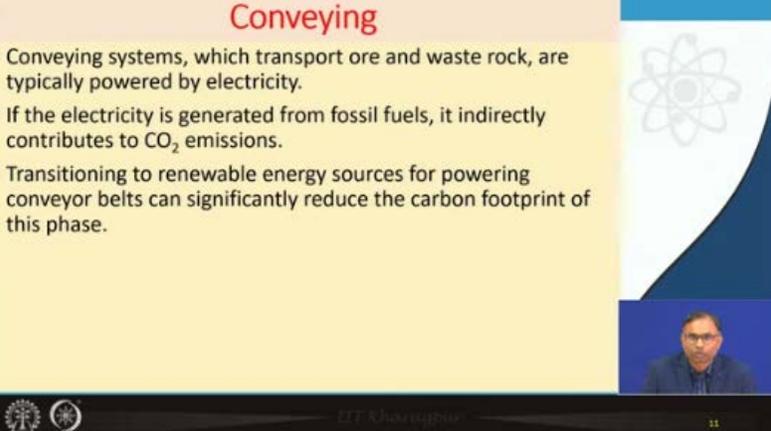
- Throughout mining process, various mobile and stationary equipment, including bulldozers, graders, and auxiliary generators, are used.
- These machines rely on diesel contributing primarily to CO₂ emissions, with trace amounts of CH₄ and N₂O.



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Conveying

- Conveying systems, which transport ore and waste rock, are typically powered by electricity.
- If the electricity is generated from fossil fuels, it indirectly contributes to CO₂ emissions.
- Transitioning to renewable energy sources for powering conveyor belts can significantly reduce the carbon footprint of this phase.



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The size and weight of haul trucks combined with the distances they travel decide how much diesel consumption is taking place. It depends on the capacity of the dumper and the distance that the dumper has to travel, which decides the fuel consumption. The more the fuel consumption, the more greenhouse gas emissions will be from the haulage system or from the truck, dumper truck system. So, the hauling phase represents a critical area for potential improvements in fuel efficiency and alternative energy use. So, mostly in general, we are using the diesel-operated dumpers. But if we can develop the technology so as to use alternate energy sources like electric vehicles or hydrogen-based vehicles, then our CO₂ emissions will be reduced. And also, when we are using diesel, we have to think about how the efficiency of the combustion can be improved. So, fuel efficiency can be increased, and when fuel efficiency increases, fuel consumption will decrease, and so also the CO₂ and other greenhouse gas emissions will decrease. These are the different unit mining operations. Now we also come to crushing and grinding. Crushing and grinding: Primary crushing is occurring in the mine itself, and then the fragmented ore or rock comes to the beneficiation plant, where it is further crushed, so the crushing and grinding phase involves breaking down the ore into smaller particles.

Hauling

- Haul trucks, which transport material from the mine to processing facilities, are among the largest consumers of diesel fuel in mining operations.
- These trucks emit substantial amounts of CO₂, CH₄, and N₂O.
- The size and weight of haul trucks, combined with the distances they travel, result in high fuel consumption and significant GHG emissions.
- This phase represents a critical area for potential improvements in fuel efficiency and alternative energy use.



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12

Crushing and Grinding

- Crushing and grinding phase involves breaking down ore into smaller particles, a process requiring substantial energy.
- This energy often comes from electricity or on-site diesel generators.
- Depending on the source of electricity, indirect CO₂ emissions can be significant.
- Diesel generators add to the direct CO₂ emissions.
- Energy-intensive nature of these processes highlights the importance of energy efficiency and the use of renewable energy sources to mitigate emissions.



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11

These processes consume a substantial energy. A significant part of our energy bill is coming from the comminution process, which is the crushing and grinding. So, this energy often comes from electricity or it is on-site diesel generators. So, depending on the source of the electricity, either you have indirect CO₂ emissions or you have direct CO₂ emissions. So, if it is a diesel-operated on-site crusher, then you will have direct CO₂ and other greenhouse gas generation. If it is electricity operated, then you will have the indirect CO₂ emissions. Diesel generators cause direct CO₂ emissions. Now, the energy-intensive nature of the combination process of the crushing and grinding process highlights the importance of energy efficiency. How can we make our process more efficient? So, when we make our process more efficient, our diesel consumption will decrease. So, our emissions will also decrease. Secondly, we should replace the diesel generator with electricity-driven equipment, or we should think about how we can increase the contribution of renewable energy sources. So, when we use renewable energy sources, they will reduce the emissions of CO₂ and other greenhouse gases. Now, apart from crushing and grinding, we have the beneficiation process, such as flotation, magnetic separation, etc., which further concentrates the ore, and these processes are also highly energy-intensive. Mostly, this equipment runs on electricity and produces indirect CO₂ emissions.

Beneficiation

- Beneficiation processes, such as flotation, magnetic separation, and leaching, further concentrate the ore and are highly energy-intensive.
- These processes often rely on electricity and produce GHG indirectly.
- Reducing the carbon intensity of these processes is crucial for minimizing their environmental impact.

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In this process, we also have to reduce the carbon intensity by developing an efficient process and reducing the electricity demand. Now, these are the different processes where they are either directly generating the CO₂ and greenhouse gases or indirectly generating the CO₂ and greenhouse gases. So we can calculate what the CO₂ generation is in each process and add them together, which is the carbon footprint. So we can say, how much carbon is produced, generated, or emitted per ton of coal produced? We can calculate the emissions from each unit's processes. Even when you do not have the experimentally

determined emission data, we can calculate using emission factors developed by IPCC for underground mines, for open-cast mines, if you know your annual production. So, you can use the emission factor to calculate how much CO₂ or greenhouse gases you are emitting, and how much CO₂ equivalent you are emitting per year. Now, knowing the CO₂ emission, we have to develop a strategy to reduce this CO₂ emission. So, what is the strategy for the reduction of CO₂ emissions? There are many strategies we can use to reduce the CO₂ emissions. First thing is electrification. Switching from diesel-powered equipment to electric equipment or hybrid alternatives. The electric vehicles can be powered by renewable energy sources such as solar and wind power, eliminating a lot of CO₂ emissions, which were happening because of the use of fossil fuels.

Strategies for Reducing Carbon Footprint

- **Electrification:** Switching from diesel-powered equipment to electric or hybrid alternatives; Electric vehicles can be powered by **renewable energy sources**, such as solar or wind power, eliminating emissions and reducing reliance on fossil fuels.
- **Automation and remote control:** Automated mining equipment, like autonomous haul trucks and remote control drills, have been increasingly implemented in mines to improve safety and efficiency.
- **Digitalization and data analytics:** Digitalized mining operations can provide real-time data on equipment performance, resource consumption, and environmental impacts. Data analytics can identify opportunities for optimization, resource efficiency, and emission reduction.
- **Hydrogen technologies:** Hydrogen fuel cells offer a promising alternative to diesel engines, providing clean and efficient power for mining equipment.
- **CO₂ capture and sequestration (CCS),** as a cost-effective strategy for mitigating climate destabilization caused by high levels of energy-related CO₂ emissions.
- All the above technologies can be termed as **Green Mining Technology.**

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Now, we can go for automation and remote control of different processes. So, when you use the automated mining equipment like autonomous haul trucks, remote control drills, they are used to increase safety and efficiency. And when your efficiency increases, your electricity demand and consumption will decrease, your emission will, CO₂ emission will decrease. Digitalization and data analytics: So, digitalized mining operations will provide real-time data on equipment performance, resource consumption, maintenance status, and environmental impact. Using data analytics, we can identify opportunities for optimization of the equipment. We can improve resource efficiency, and we can reduce greenhouse gas emissions. Hydrogen technology: hydrogen fuel cells offer a promising alternative to diesel engines, providing clean and efficient power for mining equipment. Now, there will be CO₂ emissions, we can think of CO₂ capture from the power plant and sequestration in geological formations. CCS is a cost-effective strategy for mitigating climate change caused by high levels of energy-related CO₂ emissions. So, this strategy can be used for reducing CO₂ emissions. Taken together, all these strategies, if we can use them in our mining operation, we can reduce the anthropogenic CO₂ emission from

the mining, and then we can say our mining is a green mining. So, all these processes can be termed as green mining technology. So, the adoption of green mining technology for reducing CO₂ emissions.

The mining industry in various countries globally has started using different green mining technologies. For example, in Canada, the Borden gold mine became the first all-electric underground mine in the world. So, electric equipment has replaced the traditional diesel-powered equipment with battery electric vehicles for underground operations. Also, they have used electrical haul trucks, loaders, and drilling rigs. In China, many gassy coal mines exist that emit methane, and methane emissions are a significant greenhouse gas emission. So, they have extracted CBM at the Jundhuk coal field and are using CBM as an energy source. So, when you are extracting CBM, CO₂ and methane emissions are eliminated, and you are using the CBM as an energy source, you are also getting a clean energy source. In Australia, Newmold Burlington Gold Mine in Western Australia deployed several green mining technologies. Particularly, Rio Tinto is also embracing green mining practices; it is testing green technology at two sites: methane capture in New South Wales, Australia, and a productive CO₂ storage plant in Victoria, Australia, which has stored 60,000 metric tons of CO₂. So, one site, it is capturing methane, and secondly, it is sequestering CO₂ at the other site. So, both processes are green mining technologies. In South Africa, a hybrid dump truck driven by electricity and a reserve of hydrogen fuel is poised to take the title of biggest electric mining truck. And the fuel cell electric is currently being tested in the Mogalakwena platinum group metals mine in South Africa.

Adoption of Green Mining Technology

- **Canada:** *Borden Gold Mine* became the first all-electric underground mine in the world. It replaced traditional diesel-powered equipment with battery-electric vehicles for its underground operations. Electric haul trucks, loaders, and drill rigs are examples.
- **China:** *Extraction of coalbed methane (CBM)* practiced at *Zhundong coalfield*. The CBM is used as energy source.
- **Australia:** *Newmont Boddington Gold Mine* in *Western Australia* has deployed several green mining technologies. Australia is exploring ideas to convert a decommissioned underground coal mine into a pumped hydro plant as part of a larger push to repurpose retired fossil fuel assets for renewable energy output in the *Newstan Colliery*.
- Rio Tinto is also embracing green mining practices. It is testing green technologies at two sites: methane capture in New South Wales, Australia, and a productive CO₂ storage plant in Victoria, Australia, which has stored 60,000 metric tons of CO₂ to date.
- **South Africa:** A hybrid dump truck driven by electricity and a reserve of hydrogen fuel is poised to take the title of the biggest electric mining truck.
- **The Fuel Cell Electric** is currently being tested in Mogalakwena platinum group metals mine in South Africa.

16

So, some of these mines worldwide have started adopting different green mining technological alternatives, right from using electric vehicles, extraction of CBM, CO₂

storage, using fuel cells, and also using hydrogen vehicles. So, many applications are now taking place worldwide. Now, this Green mining technology adoption is taking place. It has started, but still, the speed at which it is adopted is slow. So the transition to green mining technology demands a significant upfront investment. Why is the adoption not very fast? It is slow because transitioning from a traditional energy system to the green energy system requires a lot of upfront investment, encompassing adopting electric vehicles, renewable energy infrastructure, and advanced processing technology. As we know, the mining industry is a very capital-intensive industry, so reallocating resources to green mining technology can meet resistance from the company. Particularly, when economic returns are not immediately apparent. Miners often struggle with the time it takes to realize a return. So, the time to return on investment for green mining, with a longer payback period for certain technologies, can pose a challenge for the adoption of green mining. Small and medium-sized mines may encounter difficulties in accessing capital for investing in green mining technology. Uncertainty related to future environmental regulations also creates hesitation among the mining companies because they don't know whether the environmental regulations are changing.

So, what will be the nature of the regulation, in the near term, in the long term? Unless there is policy stability and regulatory stability, informed decision-making is critical. So, you must have the regulatory stability, as well as policy incentives, so that the mining company can transition from a traditional energy system to a green mining energy system. So, summary: this lecture section covers the following. We have discussed how the greenhouse gas emissions or carbon dioxide emissions from different unit operations of the mining and beneficiation. Then what are the strategies for reducing greenhouse gas emissions from mines, and what are the different green mining technology alternatives, and what are the barriers that we have also discussed? These are the references that have been collected from several papers and reports. So you can go through these reports. This is all for today. So, I thank you for patiently hearing. Thank you very much.

SUMMARY

This lecture session covered the following:

- Different mining unit operations contributing to Carbon emission;
- Strategy for reducing carbon emissions from mines
- Green mining technology

