APPLICATION OF CARBON FOOTPRINT IN MINING INDUSTRY

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C E R T I F I C A T E

This is to certify that the thesis entitled “**Application of Carbon Footprint in Mining Industry**” submitted by Shri Kushal Tibrewal for the final completion towards the award of Dual Degree B. Tech & M. Tech in Mining Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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DECLARATION

I certify that

- The work contained in the thesis is original and has been done by myself under the supervision of my supervisor.
- The work has not been submitted to any other Institute for any degree or diploma.
- The writing of this thesis is as per the prescribed guidelines of the Institute.
- I have taken utmost care to adhere by the norms and guidelines of the institute.
- The work of others wherever is used are cited in the reference section of the thesis.
- The referred sites for the work have been mentioned in the reference section.

Kushal Tibrewal

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ABSTRACT

Reportedly, India is the world's third biggest greenhouse emitter and thus it needs to bat for some serious mitigation actions to curb its contribution to global warming. Following this inevitable urge, India, in the 21st Conference of Parties in Paris, pledged to cut its Emissions by at least 33% of the 2005 levels and 40% of installed power capacity will be from non-fossil fuel sources. Moreover, the country intends to expand its forest and tree covers that may absorb at least 2.5bn worth of CO_2 and also replace diesel with clean energy. It is quite evident that the trending global warming menace is a consequence of the reckless anthropogenic CO_2 emissions. Therefore, in order to control it we need to keep a track of these emissions. Such an estimation of approximate values of CO_2 emissions along with few major greenhouse gases pertaining to the corresponding activity is referred to as Carbon Footprint of that activity. Mining is an indispensable activity that caters the supply of raw materials for other industries to produce the final product. Mining itself utilises enormous amount of energy in form of electricity and fuels for machineries. Moreover, it adds to concentration of greenhouse gases in the atmosphere in form of CH_4 emissions, gases due to blasting, from mineral processing plants and many more. Thus emissions from mining cannot be neglected, since it contributes significantly to the bludgeoning global warming. This project presents a case study of application of Carbon footprint in two Indian Mines to estimate the approximate emissions of CO_2, NO_2 and CH_4 as 'CO_2 – equivalent' in those mines to emphasise on the use of carbon footprint in mining industries. It also illuminates the various problems encountered while carrying out the estimations and suggests measures to improve the estimation and control of these emissions such as use of solar energy in lieu of conventional fuel based energy and regular maintenance of the mining machineries so that fuel is burnt efficiently releasing lesser emissions. It also proposes methodology to carry out carbon footprint in mines in a uniform manner so that comparison of different mines is easy. It also proposes a methodology to estimate the emission factor for HEMM used in mines in Indian working conditions.

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Chapter 1

INTRODUCTION

1.1 GENERAL

The blooming industrialization and the advent of technological up-gradations brought with it a whirlpool of environmental hazards posing serious threat to mankind as well as nature. Among the plethora of these deleterious impacts, the echo of global warming lasted a little longer so as to make the public take notice of it and become more concerned about its consequences. It is very common now-a-days to mention global warming along with climate change, even though the latter is a much broader phenomenon. Where climate change encompasses changes in all attributes relating to climate such as surface temperature, precipitation, winds, ocean currents etc., global warming is the phenomenon of rising Earth’s surface temperature over past recent years. With the onset of the 21st century, the climate scientist around the globe ascertained that global warming is happening and is rising at an alarming rate. Moreover, climatic studies provides evidence that global warming is a consequence of release and accumulation of greenhouse gases in the atmosphere due to human activities. It led the scientists to assess the potential impacts of this bludgeoning catastrophe, such as doubling of CO_2 concentrations in the atmosphere, increase of global temperature in the range of 1.5o to 4.5oC and its unequal distribution throughout the globe and also the rise of sea level by 0.3 – 0.5m.

It is evident that global warming has become the major threat of the century and so the incessant emissions of greenhouse gases (GHGs). Therefore it is the need of the hour for the public to be aware of the science, potential impacts, key challenges and solutions pertaining to climate change. Serving the purpose to supply public with a myriad of information about the prevailing threat, several independent research institutes/ organizations have cropped up in the past recent years, such as the Union of Concerned Scientists (UCS), Carbon Offset Research and Education (CORE), Global Change Research Information Office (GCRIO), Climate Strategies, Intergovernmental Panel on Climate Change (IPCC) and many others.

Treading along the path of imparting all the relevant information about climate change, by assessing its scientific basis, impacts and future risks, adaptation and appropriate mitigation, is the Intergovernmental Panel on Climate Change (IPCC). IPCC was setup in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment

Programme (UNEP) to carry out research and prepare assessment reports for governments at all levels to develop policies related to climate. Starting from 1990, the IPCC has published 5 assessments reports till date. According to their latest and the fifth assessment report it is concluded that last 3 decades are likely to be the warmest period with global temperature rise of 0.6 + 0.2 ^{o}C. Adding to the misery, the atmospheric concentrations of major GHGs have increased to an unprecedented levels. CO_2 levels have increased by 40% since the pre-industrial times. It is qualified that the concentrations of CO_2, CH_4 and N_2O have increased due to human activities and were found to be 391 ppm, 1803 ppb and 324 ppb for the year 2011.

It is now quite evident that the primary cause of the recent global warming menace is the CO_2 emissions. Thus it is required to curb these emissions and control the amount of carbon burnt. There were many initiatives taken to regulate carbon emissions like the Kyoto Protocol which is linked to the United Nations Framework Convention on Climate Change (UNFCCC). It is an international treaty that binds the countries to limit or reduce their Carbon emissions. In order to regulate the amount of CO_2 released in the atmosphere, it is required that we should be aware of how much quantity of CO_2 is actually emitted in the various day to day activities carried out by human beings respectively. That is we need to determine how much CO_2 is added up in the atmosphere during each activity (such as industrialisation, mining, construction work, daily household chores etc.). This estimation of CO_2 emitted in the respective activity is known as Carbon Footprinting. A carbon footprint, or Corporate Greenhouse Gas (GHG) Inventory, is an accounting of a company's operational emissions. The most common GHG is carbon-dioxide (CO_2), which is why greenhouse gases are often referred to as "carbon", however there are six different GHGs that make up an organization's carbon footprint. At the most basic level, the process of measuring a carbon footprint involves collecting a company's full operational data and multiplying each source by an associated emissions factor to generate a relative number, or carbon dioxide equivalent (CO_2-e). At this level of pollution, it is essential that carbon footprint must be carried out in each and every sphere of human life as far as possible. But the primary focus should be given on areas such as Industries, Construction activities and most importantly mining, since they emit a considerable amount of CO_2 during their life cycle.

1.2 MOTIVATION

Ever since the human race evolved, there is a constant strive to exploit the natural resources for their development and comfort. Gradually the greed to exploit more and more increased thus depleting the resources non-judiciously and creating numerous ecological hazards during this process. Mining is the primary activity which the humans employ to extract the raw materials. The process of mining although developed scientifically throughout these years, is still a major source of environment degradation. It emits notorious and harmful gases which, besides deteriorating human health, is claimed to be a major contributor to the present climate change havoc. Thus this project attempts to emphasise on the severity of the effects the mining activities pose on the Earth's climate by determining the emissions of major greenhouse gases due to mining activities and recommending measures to reduce the uncertainties occurring in these calculations and proposing measures to check such emissions from rising to an intolerable level.

1.3 OBJECTIVES

Although a popular concept among the scientist since decades, it is only during this recent climate change menace that carbon footprint has received its much needed attention. Gradually carbon footprint has found an indispensable place among various sectors worldwide and countries around the globe are joining hands to formulate policies to mandate the incorporation of carbon footprint into all potential spheres of human intervention. Emphasising on the need of greenhouse inventory for mining industries, this project aims to

- Calculate carbon footprint for mining activities (inventory of GHGs emitted during major activities in mining industries) vis-à-vis a case study of two Indian open cast coal mines,
- Discuss the lacunae and uncertainties faced during the calculation of carbon footprint of Indian mines,
- Propose a methodology to determine the emission factor for Heavy Earth Moving Machinery employed in mines under Indian working conditions.

1.4 ORGANISATION OF THE THESIS

The project "Application of Carbon Footprint in Mining Industry" emphasises on the use of carbon footprint in Indian mines as they are among the significant contributors of the present climate change epidemic. Literature review provides a glimpse of some research work already carried out related to carbon footprint and its applications in various sectors. The present scenario of climate change is also discussed briefly. The concept of carbon footprint and various topics related to it are also explained. Then the methodology used to carry out the field study is presented along with the results obtained. Finally methodologies are proposed to establish a uniform procedure to calculate carbon footprint for all mines and to estimate the emission factor of the mining machinery under Indian working conditions. The plan of the thesis can be summarised as follows:

1. Introduction
2. Literature Review
3. Climate Change
4. Carbon Footprint
5. Case Study
6. Proposed Methodologies
7. Conclusion and Recommendations
8. References

Chapter 2

LITERATURE REVIEW

Carbon footprint is a rudimentary concept which is yet to evolve from its primitive stage. Due to lack of proper concrete research, there is not much legitimate literature available in this regard. Most of it is form of webpages and blog writings. Nevertheless, whatever few research has been carried out it suggests that the concept of carbon footprint is equivocal and there is no exact academic definition of Carbon Footprint yet. The concept of Carbon Footprint derives from the concept of **Ecological Footprint** raised by **Wackernagel and Rees** in **1996**. However, with increasing global concern of climate change, Carbon Footprint has been developed into an independent concept with extended scopes.

The **Carbon Trust (2007)**, in order to develop a more common understanding of carbon footprint maintains its definition as: “a technique for identifying and measuring the individual greenhouse gas emissions from each activity within a supply chain process step and the framework for attributing these to each output product”. This definition aims to delineate that not only the direct processes associated with a product/activity should be included, but also the various other indirect emissions must also be taken into account.

Wiedmann and Min (2008), the definition proposed by Wiedmann states that "The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product."

Larsen and Hertwich (2009) define carbon footprint as “Carbon footprint is the life-cycle GHG emissions caused by the production of goods and services consumed by a geographically-defined population or activity, independent of whether the GHG emissions occur inside or outside the geographical borders of the population or activity of interest.” This definition refers carbon footprint to GHG emissions based on the consumption of a defined population, thus any regional or provincial estimation of the carbon footprint should not be limited to its geopolitical boundaries.

Peters (2010) gives carbon footprint a broader outlook in his definition, "The ‘carbon footprint’ of a functional unit is the climate impact under a specified metric that considers all relevant emission sources, sinks, and storage in both consumption and production within the specified spatial and temporal system boundary." This definition offers more flexibility on both objects and emission categories of interest. It also covers the essential stages of the carbon cycle with respect to anthropogenic activities.

Treptow (2010) is his article illustrates that how the basic principles of general chemistry can be applied to calculate the GHG emissions. It follows that general chemistry uses units, dimensional analysis, stoichiometry, thermochemistry and related scientific laws in order to perform the calculations for different activities that produced CO_2. Each calculation was started with a balanced chemical equation for the emission reaction related to the respective activity. Subsequently, various scientific and chemical principles were used to express these emission factors. In his article he showed the calculation for CO_2 released in cement production, gasoline combustions, and natural gas combustion. The mass of carbon dioxide produced in each of these reactions was based upon the mass of cement produced, volume of gasoline consumed, and the heat generated by burning of the natural gas respectively. Thus the main objective of his article was to demonstrate role of chemistry in global warming.

Gao *et al.* (2013) through their paper compared the various important standards used in the estimation of Carbon Footprint. They maintained that carbon footprint estimation can be classified into following categories based on its scope of implementation, namely personal, product, organisational, cities, countries etc. A personal carbon footprint quantifies the carbon dioxide emissions caused by each person via clothing, food, travelling, house etc. A product carbon footprint gauges the GHG (Greenhouse Gases) emissions over the entire life of the product (from extraction of raw material to its final consumption and the subsequent disposal). Similarly an organisational carbon footprint measures GHG emissions from all the activities in an organisation or enterprise. Thus we can see that carbon footprint studies can be so varied. So to streamline these studies and make it more comparable, eminent organisations such as the International Organization for Standardization (ISO), the World Resources Institute (WRI), the World Business Council for Sustainable Development (WBCSD) and the British Standards Institution (BSI), have proposed different kinds standards to assess the carbon footprint studies. Various Standards such as ISO14064, GHG Protocol, PAS2050, has been created based on thorough research and experimentations. According to the paper, the standards which primarily aid the estimation of organisational carbon footprint are GHG Protocol (2004), formulated and published by WBSCD and WRI and ISO14064 published by ISO. On the other hand, standards such as PAS 2050, TS-Q

0010, Product Life Cycle Accounting and Reporting Standard and ISO 14047 cater to the requirements for measuring the GHG emissions and impact of a product. Based on the area of observation, particular standards are used for respective areas.

Pandey and Agrawal (2014) reviewed the studies on the contribution of Agriculture to GHG emissions. Their research qualified that agriculture is the largest contributor to the anthropogenic emissions of greenhouse gasses. They documented various studies and researches in the field of Carbon footprint vis-à-vis Agriculture in their review. Information collected by them states that agriculture releases about 13.5% of total anthropogenic GHG emissions. Moreover, agricultural activities release approximately 4.2 to 7 Tg N annually in form of N_2O. N_2O has a very high global warming potential- 298, thus emissions, even in small amounts, cause significant impacts. Thus carbon footprint studies in agriculture comprises of mainly CH_4 and N_2O emissions. Operations like improperly managed mulching, organic manure applications and application of mineral nitrogen have increased the CH_4 and N_2O emissions. Proper agriculture management practices can help to offset the GHG emissions. An important practice to be followed is Carbon Sequestration i.e. locking the carbon within the soil itself. Thus steps have to be taken to enhance carbon sequestration, such as minimisation of soil disturbance, increasing organic matter inputs and improvement in nutrient status. They maintained that Carbon footprint in agriculture can help to improve environmental efficiencies of agricultural sector. Finally they reviewed the various case studies carried out to estimate the carbon footprint in cultivation systems and food which mainly involved CH_4 emissions from rice cultivations and N_2O from the rest. Comparing the results of these case studies indicated the contribution of different activities and management techniques in the GHG emissions. They urge that although studies in agricultural carbon footprint is increasing, it is difficult to compare to the individual results due to lack of uniform and specific standards for calculation of carbon footprint in agriculture.

Rongqin *et al.* (2010) estimated the carbon emissions of fossil and rural biomass energy of different regions of China and established a carbon footprint model based on energy consumption. He categorised five types of industrial spaces: agricultural space, living & industrial-commercial space, transportation industrial space, fishery and water conservancy space, and other industrial space. He matched these industrial spaces with energy consumption items and studied the carbon emission intensity for each industrial space. The analysis carried out by the author yielded the following conclusions: a) total carbon emission due to energy consumption in China 2007 is 1.65 GtC wherein the fossil energy contributed 89%, b) living & industrial-commercial space and transportation industrial space were the high carbon emission industrial space with emission intensity amounting to 55.16 t/hm^2 and 49.65 t/hm^2 respectively, c) The industrial activities in China 2007 brought about 28.69 x 10^6 hm^2 of ecological deficit by causing 522.34x10^6 hm^2 of carbon footprint, d) lastly the per unit carbon footprint of these industrial spaces showed a declining trend from east to west of China. The proposed mitigation measures include use of clean energy, reducing use of fossil and rural biomass energy, enhance the carbon fixation efficiency of productive lands, reduction of carbon emission intensity of high carbon emission spaces through industrial regulations and improving energy efficiency and structure.

Paulson (2015) highlighted the importance of reducing carbon emissions in mining. Mining industry is under great scrutiny as the extraction process is the greatest contributor to greenhouse gas emissions following the subsequent mining activities such as cleaning, drying and screening as the second largest contributor. Thus mining industries are growing more concern to reduce their carbon emissions. Teck Resources, a British Columbia- based coal exporter uses gas chromatography and liquid chromatography for monitoring GHG emissions to help various mining companies reduce their carbon emissions. Moreover, mining industries are getting inclined to renewable sources to meet their energy demands instead of traditional energy sources such as diesel for heavy machineries and transportation in order to offset their GHG emissions.

Turner and Collins (2013) compared the carbon footprints of OPC binder and geopolymer binder used to make concrete along with a comprehensive analysis of carbon dioxide equivalent emissions per unit during manufacturing of raw materials, mining, concrete production and construction activities for making 1 m^3 of concrete. Concrete is the most extensively used raw material in construction. The OPC binder traditionally used in concrete contributes 5-7% of global CO_2 emissions, whereas an alternative binder composed of alkali-activated fly ash, termed as 'geopolymer' binder has the potential to lower these emissions from about 26-45% to even 80% of that of OPC binder emissions. To estimate the CO_2-e arising from each activity, the type and quantity of fuel consumed was identified by the authentic audited reports. CO_2-e was calculated as the product of 'Quantity' of fuel consumed per activity, 'Energy content (EC)' of the fuel used and its 'Global warming potential (GWP)' determined by the sum of emissions of the individual gases (consisting of CO_2, methane, nitrous oxide and other synthetic gases) released due to the fuel consumption. 2012 Australian National Greenhouse Accounts (NGAs) factors were used to determine the EC and GWP of the specific fuels used. This was carried out for each activity involved to produce 1 m^3 of concrete such as manufacture of Sodium Silicate, OPC, Fly ash, aggregates, and curing. Finally the total emissions from OPC concrete and Geopolymer concrete were recorded as 354 kg CO_2-e/m^3 and 320 kg CO_2-e/m^3 respectively. When compared with earlier studies the obtained difference in emissions is mere 9% compared to estimated 26-45% and 80% in earlier studies. It was concluded that such deviation occurred due to inclusion of emissions from transportation and mining of raw materials, significant energy consumed during Sodium Silicate manufacturing and lastly due to high energy consumed for high curing temperature in case of geopolymer binder which is negligible in case of OPC binders.

CETCO (2014) estimated the carbon footprint of an Organoclay manufactured by it. It is manufactured from processing Sodium Bentonite (mined and processed American Colloid Company's plant in Lovell, WY) and a quaternary amine compound. The scope of calculation covers all major activities from raw material production (including mining and transport of Bentonite) to packaging of final product. Assumptions made in the calculation include: transport distance of 1690 miles of mined sodium bentonite from Lovell to processing plant, trucks travel at full capacity with their emission factors taken from USEPA (2008a, 2008b), emissions from quaternary amine production were taken from AkzoNobel 2013, and the emissions at the plant during processing of the organoclay were calculated using the energy and fuel consumption data obtained from their yearly report. Consequently, the carbon footprint calculated was found to be 2070 Kg CO_2eq/ metric ton of Organoclay produced.

The Carmichael Coal Mine and Rail Project SEIS: Hydrogeology Report, prepared by GHD Pty Ltd on behalf of and for Adani Mining Pty Ltd quantifies the carbon emissions by the mine within Scope 1 and Scope 2 of the GHG Protocol comprising of the following sources: Grid electricity, diesel for stationery energy purposes, explosives-ANFO and Emulsion, waste water handling, fugitive methane from open cut mine as well as underground mine and lastly vegetation removal. The report concluded the total average carbon emissions to be approximately 2,286 kilo tonnes CO_2 per annum with electricity usage being the largest contributor followed by diesel consumption. These estimates are claimed to be made using the National Greenhouse Accounts (NGA) Factors. Following the estimation, various mitigation and energy management steps are suggested to reduce greenhouse emissions separately for the construction phase and operation phase.

Chapter 3

CLIMATE CHANGE

3.1 GENERAL

As early as the mid-twentieth century, scientists worldwide have documented the mounting levels of carbon dioxide and other greenhouse gases in Earth's atmosphere. Several tests and experiments concluded that Earth's infrared radiations are absorbed by these greenhouse gases which raise the atmospheric temperature. Eminent Scientists and Organisations around the world such as the U.S. scientists, NASA, NOAA scientists, Japan Meteorological Agency and others who are keeping a constant track on the atmospheric temperature have reported that the global temperatures have been rising relentlessly due to the emissions of these greenhouse gases. According to them the year 2014, has shattered all records, making it the hottest year. Thus climate change has become a serious threat and it is the need of the hour to take appropriate actions. Even the Intergovernmental Panel on Climate Change's (IPCC) latest report on issues of global warming vividly blames humans as the primary cause of climate change. The climate scientists say they are at least 95 percent certain that humans, with their activities such as Constructions, Mining, Industrialisation, Transportation etc. are responsible for the warming oceans, rapidly melting ice and rising sea levels that have been observed since the 1950s.

Scientists and Meteorologists all over the world have attributed this global temperature rise to the mounting levels of CO_2 emissions and other greenhouse gases. The World Meteorological Organization reported that the concentration of greenhouse gases reached a new record high in 2013, propelled by a surge in levels of carbon dioxide raising serious threats of global warming. Scientists who contributed to the report, called the "Greenhouse Gas Bulletin," remarked that CO_2 levels rose more between 2012 and 2013 than during any other year since 1984. The report also showed that between 1990 and 2013, the energy in the atmosphere increased by 34%. The surge was driven by a concentration of CO_2 that is 42 % higher than the level in the pre-industrial times. Methane and nitrous oxide were 153 % and 21 percent higher, respectively, although their overall numbers are much lower than carbon dioxide's.

Concerned with the incessant rise in the CO_2 levels, the scientists warned that emissions of carbon dioxide and other greenhouse gases will need to be cut in order to keep the increase in average global temperature to less than 3.6 degrees Fahrenheit (2 degrees Celsius), and avoid the most devastating effects of global warming. The benchmark of 3.6 degrees Fahrenheit was set by climate negotiators in Copenhagen in 2009. Thus to keep the temperature rise within this limit, we cannot afford to burn and emit more than 1,000 billion tons of Carbon. But according to scientists we have already emitted 54% of it and it is expected that even if measures are taken to reduce this emissions, the 3.6 degree mark is still likely to be surpassed.

The profound effects of CO_2 emissions and other greenhouse gases can be seen in form of the threatening temperature rise. Alongside this global nightmare other effects also include sea level rise, melting glaciers and deteriorating health among humans and danger to other living organisms due to rise in the levels of such harmful gases. It is expected that sea levels could rise as much as 3 feet (0.9 meters) by the year 2100. This is an increase from the estimated 0.9 to 2.7 feet (0.3 to 0.8 meters) of sea-level rise that was predicted in the 2007 IPCC report. Global temperatures are also likely to rise by between 0.5 and 8.6 degrees Fahrenheit (0.3 degrees and 4.8 degrees Celsius) this century, depending on global levels of carbon emissions. Moreover continued emissions of greenhouse gases will lead to warming and changes in the total climate system. Thus it is evident that a substantial and sustained reductions of greenhouse gas emissions is required to prevent the disastrous climatic change.

3.2 KEELING CURVE

In 1953, a scientist named Charles David Keeling started to measure the amount of carbon dioxide (CO2) in the atmosphere around Pasadena, Calif. Soon, Keeling expanded his CO_2 research to areas such as Big Sur, near Monterey, Calif.; the Olympic Peninsula in Washington; and the mountains of Arizona. He observed an interesting pattern everywhere he went, CO2 levels increased at night, and levelled off at about 310 parts per million (ppm) in the afternoon.

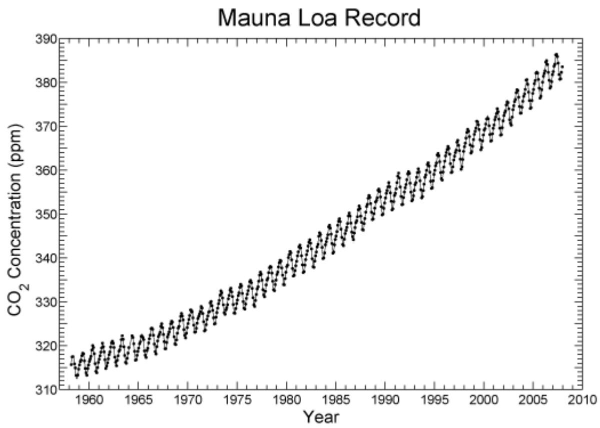


Figure 1. The Keeling Curve shows that atmospheric carbon dioxide levels are increasing, and at a faster rate each year
(Source: http://www.livescience.com/29271-what-is-the-keeling-curve-carbon-dioxide.html)

Keeling concluded that this increase during the night time was primarily due to localized respiration from plants. As Keeling's research spread, he was invited to expand his research to places like the Mauna Loa Observatory in Hawaii, and Antarctica. Analysing the data gathered by his monitoring stations, Keeling once again discovered a seasonal rhythm in CO2 levels. In 1958 at Mauna Loa, Keeling observed that CO2 levels peaked in May, and then dropped to a low in October; the May/October pattern was repeated in 1959.

"We were witnessing for the first time nature's withdrawing CO2 from the air for plant growth during summer and returning it each succeeding winter," Keeling was quoted as saying by the Scripps Institution of Oceanography.

Keeling also discovered that as the years passed by the amount of CO2 in the atmosphere was gradually increasing due to the combustion of fossil fuels. Of even greater concern to Keeling was his discovery that the rate of increase was sharper each successive year, giving Keeling's CO2 chart a distinctive upward curve, now called the "Keeling Curve."

Keeling's record of data from Mauna Loa is considered one of the best and most consistent climate records anywhere, though scientists also use other sources for atmospheric data, including samples of air trapped in polar ice, to analyze CO2 levels in past millennia.And when the Keeling Curve is added to atmospheric research from the past, it shows a trend that has alarmed scientists worldwide: CO2 levels are rising at a dramatic pitch, one unseen in the entire geologic record.

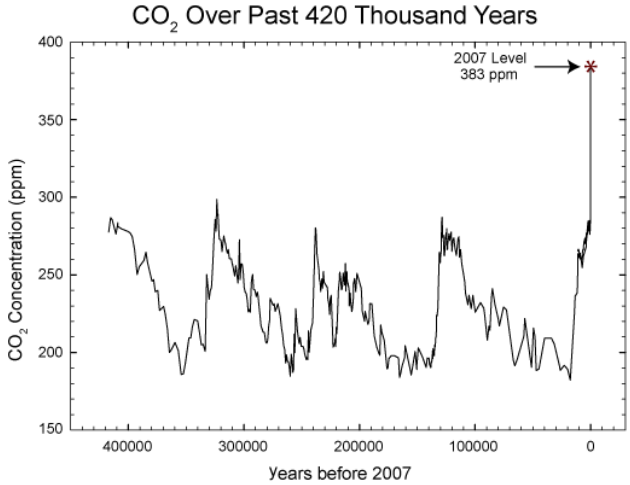


Figure 2. The rate at which atmospheric carbon dioxide levels are increasing is unprecedented (Source: http://www.livescience.com/29271-what-is-the-keeling-curve-carbon-dioxide.html)

Levels of CO2 will soon reach heights of 400 ppm and higher — levels not seen in millions of years, with unknown consequences for the planet. Though David Keeling passed away in 2005, his son Ralph continues his father's CO2 research efforts at the Scripps Institution.

3.3 THE KYOTO PROTOCOL

Heeding the credence of the global crisis, countries began to realise it is high time they took appropriate actions. This paved way for the United Nations Framework Convention on Climate Change (UNFCCC), a convention adopted at the "Rio Earth Summit" in 1992. It is an international treaty aimed at reducing the greenhouse emissions. It entered into force on 21st March, 1994 with 195 countries participating today. The countries that ratified to the convention are called "Parties to the Convention". Even after a successful launch of the Convention, years passed by, countries realised that the reduction provisions were inadequate and urged on a more firm and binding commitment - The Kyoto Protocol. It a legally binding agreement between the Parties to reduce their collective emissions of greenhouse gases. It was adopted in Kyoto, Japan in December 1997 and entered into force on 16 February 2005. It shares the ultimate objective to stabilize the atmospheric GHGs concentrations at a level that will prevent any dangerous interference with the climate system. It splits the Parties into Annex-I (the developed and industrialised countries), Annex-II and Developing Countries. Annex-I countries have a binding commitment to report and reduce their own GHGs emissions and also help the non-Annex-I (they do not have a legal binding to reduce their emissions) countries in controlling their emissions. Thus, the Kyoto Protocol ensures a more stringent commitment towards the Convention from the Parties.

3.4 INDIAN SCENARIO

As claimed to be the world's third biggest greenhouse emitter presently, India needs to bat for some serious mitigation actions to curb its contribution to global warming. Following this inevitable urge, India's honourable Prime Minister, Mr. Narendra Modi, in the 21st Conference of Parties in Paris, pledged to cut India's Emissions by at least 33% of the 2005 levels and 40% of installed power capacity will be from non-fossil fuel sources. Moreover, the country intends to expand its forest and tree covers that may absorb at least 2.5bn worth of CO_2 and also replace diesel with clean energy.

Hovering over the past, it reveals that India signed the UNFCCC on 10 June 1992 and ratified it on 1 November 1993. As discussed under the UNFCCC, developing countries such as India do not have a legal binding to reduce their GHG emissions unlike the developed countries, owing to their small contribution to the greenhouse problem as well as inadequate financial and technical capacities. According to the Kyoto protocol, the able developed countries are to support the developing countries in controlling their greenhouse emissions. Thus, ratifying to the protocol makes India a beneficiary to the foreign technology and finances in mitigating climate change and promote sustainable development.

The prime agency to foresee climate change issues in India is the Ministry of Environment and Forests along with India Meteorological Department (IMD) and Technology Information, Forecasting and Assessment Council which observes various climatic parameters and facilitates environmentally sound technology respectively. Moreover, the Government of India prepares a report of the national greenhouse gas inventory (a detailed account of greenhouse gas emissions within various sectors throughout the country) to comply with the provisions under the UNFCCC which is called India's Initial National Communication to the UNFCCC (NATCOM). Besides, it has carried out its own survey report of total emissions throughout the nation in form of Indian Network for Climate Change Assessment (INCCA), and participated in studies such as Asian Least-cost Greenhouse Gas Abatement Strategy (ALGAS).

Chapter 4

CARBON FOOTPRINT

4.1 CONCEPT OF CARBON FOOTPRINT

It is by far established that the threat of global warming is very real and is indeed, on a rise. Going by the saying that what is measurable can be manageable, it is thus recommended to keep track of the emissions that is believed to be a primary cause of the climate change. It is this accounting of greenhouse gas emissions from various human activities, which is referred to as “Carbon Footprint”.

The exact academic definition of carbon footprint is still equivocal as it is still in its rudimentary stage. But various forms of definitions have been established by different people based on its application and scope and the understanding of the people. To trace back its origin, the concept of carbon footprint is believed to have been originated from the existing concept of “Ecological Footprint”- which refers to the productive area of land and sea required to sustain human population. Based on this concept, carbon footprint refers to the area of land that is required to assimilate the amount of CO_2 emitted by human activities. Subject to changing climatic conditions and understanding of humans about the climate impacts, the concept of carbon footprint kept on modifying from time to time. This constant modification of concept due to variation in its application and the need of a global indicator of the impact of present climate havoc, got carbon footprint its present definition – total amount of carbon dioxide emitted over a period, directly or indirectly due to any human activity.

Carbon footprint can be classified based on its area of application as personal, organisational and product carbon footprints. Personal carbon footprint accounts for the CO_2 emitted by an individual due to its clothing, food, shelter, work, transport and other activities of daily life. Organisational carbon footprint measures the emissions from all activities conducted by an organisation (such as due to consumption of energy, industrial processes, consumption of fuels to run machinery or for transportation and commuting). A Product carbon footprint records the CO_2 emitted during the complete life-cycle of any product, right from extraction of raw materials to its final end use and later recycling.

4.2 CARBON FOOTPRPINT STANDARDS

As unclear as the concept of carbon footprint is, so is its application. Lack of uniformity in calculation of emissions makes it impossible to compare different organisations or products based on its carbon footprint evaluation. Thus, international organisations got together to compile various standards and programmes to make the results of carbon footprint comparable and uniform. The carbon footprint standards can be broadly classified as Organisational carbon footprint assessment standards and Product carbon footprint assessment standards.

Organisational Carbon footprint Assessment Standards

The methodologies and guidelines formulated in these standards focus on the carbon footprint calculations of an organisation. The major organisational standards are:

- The Greenhouse Gas (GHG) Protocol

  The GHG Protocol Corporate Standard was developed hand in hand by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) in 2004. It provides organisations and industries with relevant tools and guidelines to formulate their own GHG inventory and record their emissions. It focusses only on the reporting and quantification of GHG emissions and not on verification process.

- ISO 14064

  It was developed by ISO in 2006, which provides a globally agreed framework for accounting GHG emissions, mitigation techniques to help companies measure and check their respective carbon emissions.

Product Carbon footprint Assessment Standards

The methodologies and guidelines formulated in these standards focus on the carbon footprint calculations for a life-cycle of a product. The major product standards are:

- PAS2050

  It developed by the British Standard Institute for UK's Department for Environment, Food and Rural Affairs (DEFRA) and the Carbon Trust in 2008 to assess the GHG emissions of goods and services.

- Product Life Cycle Accounting and Reporting Standard

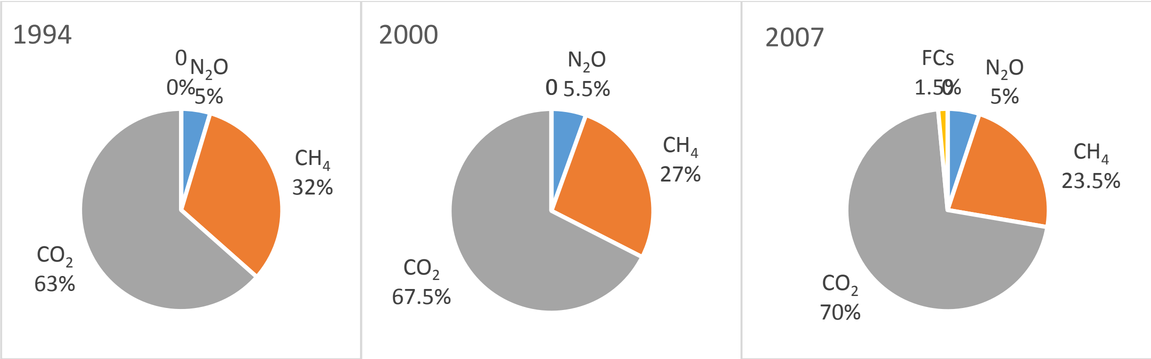
  Developed by WRI and WBCSD in 2011 provides method to prepare the GHG inventory by taking into account the impacts of even the upstream and downstream operations of company involved in the life-cycle of a product.
- ISO14047

  It is an international standard relating to the carbon footprint of products, developed by ISO and compiled in two parts - quantification and communication.

4.3 REPORTING OF CARBON FOOTPRINT

As the need for calculating Carbon footprint grew, it paved way for an international platform, the United Nations Framework Convention on Climate Change (UNFCCC), to report the GHG inventory prepared by different countries. Under the programme of UNFCCC, different countries signed the Kyoto Protocol, a treaty which aims to reduce the greenhouse gas emissions. Till date, 195 countries have signed the treaty and participated to control their respective carbon emissions and are referred to as the “Parties to the convention”. According to the protocol, different countries have a varying level of responsibility towards limiting their emissions. The developed countries have a legal binding to report and take immediate steps to check their emissions within the specific limit, whereas the developing nations are required to report their total emissions but are not compelled to check these. Moreover, it is proposed that the developed nations must provide the developing countries with appropriate technological assistance to reduce their emissions.

India being a developing nation, does not have a legal binding to control its emissions, but since it is a participant in the protocol, it is a beneficiary to the technological support from the developed countries. Presently, India is stated as the third largest emitter with 5.2% of total global emissions. The other leading contributors are China (emitting about 21.1%) and the United States of America (emitting about 14.1%). India signed the UNFCCC in the year 1992 and reports it emissions to it via the National Communication to the UNFCCC (NATCOM). India has prepared two reports of National Communications, which contained the detailed estimation of emissions from major sectors, for the year 1994 (Initial National Communication) and 2000 (Second National Communication). Apart from submitting for the UNFCCC, India developed a GHG inventory of its own for the year 2007 which was brought out by the Indian Network of Climate Change Assessment (INCCA). The trend in the GHG emissions for the years 1994, 2000 and 2007 are presented in Figure 3.



N_2O = Nitrous Oxide, CH_4 = Methane, CO_2 = Carbon Dioxide, FCs = different forms of Fluoro-Carbons

Figure 3. Trend in GHG emissions for the years 1994, 2000 and 2007
(Source: "India: Greenhouse Gas Emissions 2007", INCCA, 2010)

4.4 CARBON FOOTPRINT IN MINING vis-à-vis INDIAN SCENERIO

Mining sector is one of the most fundamental sectors. It involves extraction of minerals which cater to the need of raw materials for many basic industries and a key resource in the process of development. India, having abundant reserves of minerals, has an enormous potential to develop through mining sector. The judicious and planned exploitation of these reserves can make the country self-sufficient in meeting its energy demands, raw material requirements for industrial development and foreign trade in form of mineral exports. Thus, mining is a very crucial industry for a developing nation like India.

The mining sector in India has grown remarkably since 1952 with value of mineral production reaching the level of Rs. 282726 crores in 2013-14 from Rs. 85 crores in 1952. Moreover, the total number of reporting mines in 2013-14 (excluding those of petroleum (crude), natural gas (utilised), atomic and minor minerals) were found to be 3699. Of these, 552 mines belonged to coal & lignite, 663 to metallic minerals and 2484 to non-metallic minerals. The reported production of coal and other important minerals have also shown a spectacular rise. The coal produced in 2013-14 was reported to be in 566 million tonnes which was nearly 15 times of that produced in 1952. Also, the production of iron ore, bauxite and chromite has increased significantly since 1952, with the recent amounts being 152 million tonnes, 21.7 million tonnes and 2.85 million tonnes respectively for the year 2013-14. To supplement this extraordinary rise in production, mining has evolved technologically over the years into a gigantic industry with an ever increasing number of machineries comprising of Dumpers, Shovels, Excavators, Drills, Crushers, Surface Miners etc.

One of the major uses of mining is the extraction of coal and other conventional fuels to meet the energy requirements of the country. Energy is referred to as a `strategic commodity' and any uncertainty in its supply can be detrimental for the growth of developing economies such as India. As the energy requirement is increasing at a very rapid rate, maintaining a balanced and continuous supply is of prime importance. And, it is found that Coal and Lignite are the primary sources of energy production in our country accounting for almost 74% of the total production for the year 2013-14. Electricity generation is the biggest consumer of coal with thermal power plants accounting for a whopping 70.25% of the total installed capacity in the country, followed by steel industries.

Thus, it is quite evident that our country relies largely on mining industry for its energy requirements. Mining, as helpful as it may be, but comes with a cost. The cost of our environment. Mining involves use of heavy machineries, blasting equipment, mineral processing plants, and coal-handling plants etc. which are a huge source of GHGs. Therefore, mining is a significant contributor to the present global warming menace due to release CO2 and other GHGs. And the scale at which it is happening in our country, it cannot be neglected. Thus, Carbon Footprint is very essential to track and check the emissions caused by mining.

4.5 METHODOLOGY FOR CALCULATING CARBON FOOTPRINT

Following the steps from the GHG Protocol, the basic methodology involved in calculating the carbon footprint for a mine is as follows:

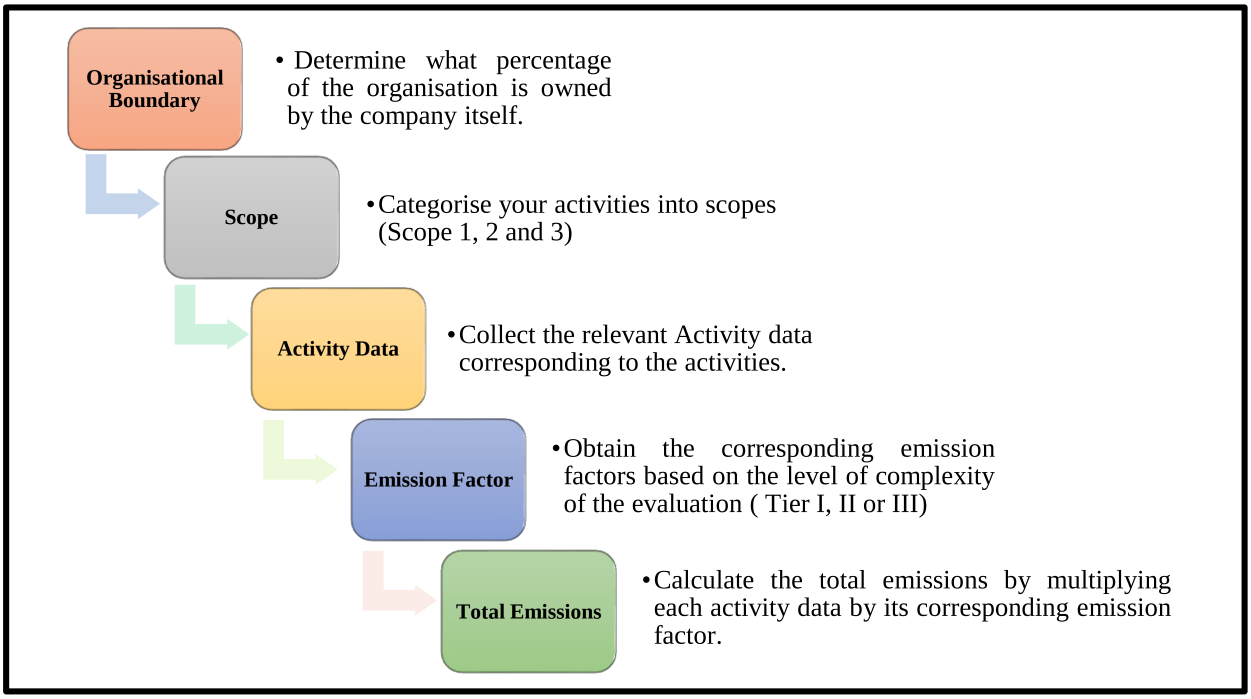


Figure 4. Methodology for calculating carbon footprint

1. **Organisational Boundary**

   The first step is to limit the boundary of the study i.e. to identify the activities which are under direct control of the company and which are out sourced. And within the activities that are under direct control which activities are to be considered for accounting.

2. **Scopes**

   Once the activities are listed, they are need to be categorised into their respective Scopes. According to GHG Protocol, any activity can be put under one of the following scopes:

   - Scope 1: These are direct emissions by the activities own or controlled by the mine. These activities release emissions straight into the atmosphere.
   - Scope 2: These are indirect energy related emissions. This scope includes those activities which release emissions and are associated with the consumption of some form energy such as purchased electricity, heat, steam and cooling. These are referred to as indirect as these emissions are caused due to the requirement of the mine but these are not produced or owned by the mine itself.
   - Scope 3: Includes activities performed by the mine personnel but occur at places which are not under the mine's control such as travelling by bus to work, waste disposal, out sourced activities etc.

3. **Activity Data**

   It gives the amount of consumption of any source responsible for emissions. For e.g. the amount of electricity consumed in kWh, litres of diesel burnt in machinery and employee vehicles, litres of gas used for cooking, cubic metres of water supplied etc.

4. **Emission Factor**

   It is the value of the emissions released per unit of activity data of the respective source. For e.g. amount of CO_2 released in kgs per unit kWh of electricity consumed or amount of CH_4 released in kgs per unit litre of fuel burnt by a vehicle or a machinery etc. Emission factors (EF) can be broadly classified as two types, Default emission factors and Country specific emission factors. Default EFs are those which are developed by international organisation and can be used globally for activities anywhere in the world, whereas Country specific EFs are developed by government organisations of the country for using in the activities conducted within their own country. Since Country specific EFs are estimated taking into account the conditions prevailing in that country, thus using the EFs developed by the country where the organisation belongs, will provide more exact results of emissions. According to IPCC Guidelines, based on the type of emission factors used, the estimation of carbon footprint can be categorised into three tiers of complexity.

- Tier 1: When the organisation uses the default EFs.
- Tier 2: When the organisation uses the country specific EFs
- Tier 3: When the organisation uses the country specific EFs along with taking into account the impacts of combustion technology and operating conditions, quality of management, control technology and other on-site conditions.

5. Total Emissions

Finally the total emissions from any source is obtained by multiplying the activity data and the emission factor used. The activity data is multiplied by the emission factor for each greenhouse gas to be measured to obtain the total emissions of that particular gas by the source. Finally every gas, other than $CO_{2,}$ is converted to CO_2-equivalent

(CO_2-e) by multiplying the total emissions by its corresponding Global Warming Potential. Then finally the total emissions of all gases from the source is expressed in terms of kgs of CO_2-e emitted by summing up the total emissions for each gas.

Chapter 5

CASE STUDY

5.1 STUDY AREA

The study was conducted for two mines under the Mahanadi Coalfields Ltd. (MCL), a subsidiary of Coal India Ltd., situated in the eastern region of India in the state of Odisha belonging to the Ib-valley Area. The mines are located in Ib- Valley Coalfield, Jharsuguda district, Orissa. The two Open-Cast Projects are Samleswari OCP and Lajkura OCP.

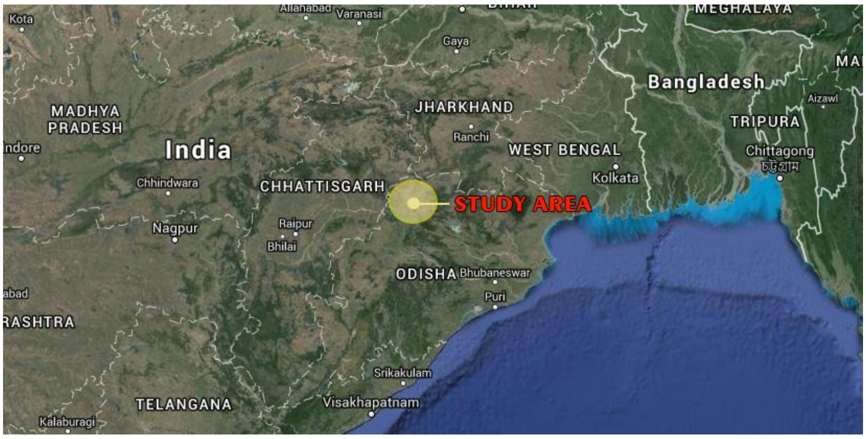


Figure 5 Study Area Location
(Source: Google Maps)

Samleswari OCP

Figure 6. Samleswari OCP

Samleswari OCP is situated in the IB Valley area in the state of Orissa. The block is approachable from Sundargarh town, lying at a distance of 40 km by road, the nearest railway station is Himgir on Bombay Howrah mail line. It lies at a distance of 36 km by road. The elevation of the area varies from 245m to 320 m. The mean temperature ranges from 8^{o}C (winter season) to 44.7^{o}C (pre-monsoon cyclone season). The monthly mean wind speed at 8:30 hr. varies from 1.5 to7.0 km/h during the year against 1.1 to 8.3 km/h at 17:30 hr. Samleswari OCP is a larger mine with a production capacity of 15 MTY and manpower of approximately 850 people using dragline, surface miner and shovel-dumper combination for coal excavation.

Lajkura OCP

Figure 7. Lakura OCP

Lajkura OCP is situated in the IB Valley area in the state of Orissa. The block is approachable from Brajrajnagar (Tahasil HQ) (about 3km East of the block), the nearest road is 2 km all weather road to Brajrajngar, the nearest railway station is Brajrajnagar railway station on Howrah- Mumbai line of south Eastern railway at a distance of about 2 km. The elevation of the area varies from 232 m to 278 m above MSL. The general slope is towards Bagachhopa nalla in the north and towards railway line in south. The mean temperature ranges from 8^{o}C (winter season) to 44.7^{o}C (pre-monsoon cyclone season). The monthly mean wind speed at 8:30 hr. varies from 1.5 to7.0 km/h during the year against 1.1 to 8.3 km/h at 17:30 hr. Lajkura OCP carries out mining mostly with only the shovel-dumper combination with a production capacity of 3 MTY and employing about 450 of manpower.

5.2 METHODOLOGY

The methodology was based on the standards laid down as per the Greenhouse Gas (GHG) Protocol. It involved setting up the **organisational boundary** within which the sources of emissions will be considered. Categorising the **Scopes** of these sources. Recording the **activity data** corresponding to each source and calculating the emissions from each source by multiplying the respective activity data with its corresponding **emission factor**. Finally, evaluating the total Carbon footprint by summing up the emissions from individual sources. The emissions factors used in this project, according to the IPCC Guidelines, belong to Tier 1 and Tier 2.

Organisational Boundary

Since this project aims to introduce the idea of carbon footprint in mining and emphasising on the importance to apply it more thoroughly, the boundary of this project is limited to mine-lease boundary. Moreover, the unavailability and inaccessibility of certain activity data forced to limit the boundary to avoid greater uncertainties and discrepancies in results.

Scopes of the Sources

The sources considered in this project fall into Scopes 1 and 2 as per the GHG Protocol standards.

- Scope 1 emissions: These are the direct emissions as it occurs on-site from the Heavy Earth Moving Machinery (HEMM) due to combustion of fuel (High Speed Diesel).
- Scope 2 emissions: These are the indirect emissions as they do not occur on the mine site itself but occur as a result of consumption by the mines. It includes the emissions due to consumption of electricity in the mines as generation of this electricity creates emissions at the Thermal Power Plants.

Activity Data

This gives the amount of sources consumed which are responsible for the emissions. For, HEMM it is the amount of fuel (HSD) consumed in litres by the machines and for electricity it is the kWh of energy consumed by the different sections of mines within the project boundary.

Table 1. Activity Data for Samleswari OCP

SCOPE	SOURCE	EQUIPEMENT		CONSUMPTION	WORKING HOURS
		No.	Model		
2	Electricity (kWh)			**1186531**	
1	High Speed Diesel (litres)				
		DUMPERS			
		50 Te			
		2789	210M	4477	141
		2790	210M	2318	85
		2791	210M	3640	118
		2885	210M	5558	177
		2886	210M	3369	125
		2923	210M	1147	34
		2935	210M	6016	192
		2984	210M	2425	75
		3160	210M	5731	188
		3161	210M	2348	80
		3164	210M	4595	174
			TOTAL	**41624**	
		60 Te			
		3313	BH50M-1	8274	298
		3333	BH50M-1	7407	263
		3334	BH50M-1	9361	320
		3361	BH50M-1	8693	280
		3374	BH50M-1	6869	229
		3380	BH50M1	2226	65
		3400	BH50M-1	4926	171
		3401	BH50M-1	1281	46
			TOTAL	**49037**	
		100 Te			
		1115	BH-100	4960	102
		1171	BH-100	6894	147
		1178	BH-100	10325	231
		1179	BH-100	10637	369
		10133	HD-785	13687	364
		10144	HD-785	12519	327
		10145	HD-785	8064	213
		10146	HD-785	14638	369

			TOTAL	**81724**	
		WATER SPRINKLER			
		325	BEML	5104	230
		331	BEML	3572	155
		372	BEML	574	25
		24048	BEML	4486	264
		24049	BEML	1841	85
			TOTAL	**15577**	
		DOZERS			
		G-10878	BD-355	6189	169
		G-10798	BD-355	2812	75
		G-11147	BD-355	9724	237
		G-11301	BD-355	5614	140
		G-11355	BD-355	10994	286
		G-11736	BD-355	11301	241
		103357	SD32AW	6253	199
		103366	SD32AW	908	33
			TOTAL	**53795**	
		GRADERS			
		6ZJ00525	CAT 16 H	1092	53
			CAT 14 M	6151	247
			TOTAL	**7243**	
		DRILLS			
		6021116	RECP-650	3570	128
		6021117	RECP-650	3820	131
		6021119	RECP-650	4100	120
		605635	IDM-30	5400	163
			TOTAL	**16890**	
		SHOVELS			
		10007	BE-1600	19343	209.5
		10008	BE-1600	16532	190.5
		10088	BE-1000	18161	316
		16079	BE-300	7456	297
		20	SURFACE MINER	36896	429
		24	SURFACE MINER	26712	321
			TOTAL	**125100**	
		AUXIALLARY			
		407297	RT--740 CRANE	402	48
		407304	RT-880 CRANE	779	70
		690	ESCORT HYDRA	208	48
		RHINO-90	ACE-	250	102

			CRANE		
		B-18036	BL14TH TYRE HAND	340	42
		PL-2248	WA-200	234	38
			TOTAL	**2213**	

Table 2. Activity Data for Lajkura OCP

SCOPE	SOURCE	EQUIPEMENT		CONSUMPTION	WORKING HOURS
		No.	Model		
	Electricity (kWh)			**377537**	
2					
	High Speed Diesel (litres)				
1		**DUMPERS**			
		50 Te			
		2985	210M	300	10
		2871	210M	3230	113
		2883	210M	5025	167
		2884	210M	702	22
		2898	210M	355	13
		2928	210M	2903	112
		2933	210M	4181	138
		2936	210M	3075	107
		2938	210M	1013	31
		2786	210M	3958	139
		2932	210M	2123	67
		2836	210M	846	30
			Total	**27711**	
		60 Te			
		60020	BH60M	4135	198
		60019	BH60M	3832	195
		60032	BH60M	3957	177
		60031	BH60M	4570	227
		3320	BH50M	6514	247
		3321	BH50M	2817	117
			Total	**25825**	
		EXCAVATOR			
		55007/EXC-	DEMAG H55N	6710	196

		2579	HYD.		
		55009/EXC-2580	DEMAG H55N HYD.	6781	182
		G-10062/EXC-2574	BE-100 HYD.	955	22
			Total	**14446**	
		DRILL			
		6020815/DRC-1142	RECP-650 D	140	5
		201206782/N.A.	IDM-30	250	9
			Total	**390**	
		DOZER			
		G-12962/T-2964	D155A-1	6778	188
		G-10835/T-2186	D-355A-3	5505	171
		G-11102/T-2713	D-355A-3	4646	132
		G-11354/T-2865	D-355A-3	2614	60
		B-10021	WHEEL DOZER (BD30W-1	1695	68
			Total	**21238**	
		GRADER			
		3184/G-390	MOTOR GRADER BG825	1515	77
			Total	**1515**	
		WATER SPRINKLER			
		370/WS-215	28KL	2216	105
		371/WS-216	28KL	1800	84
			Total	**4016**	
		AUXILLIARY			
		11014257/MC-472	ACE RH1 NO-90C CRANE	135	68
		E-26625/MC-199	ESCORT CRANE	10	8
		12224/H-57	TYRE HANDLER	25	12
			Total	**170**	

Emission Factors

Table 3. Details of the Emission Factors used

CS	COUNTRY SPECIFIC			D	DEFAULT						
DEFRA EMISSION FACTORS											
FUEL/SOURCE				kg CO2-e		kg CO2	kg CH4	kg N2O	Scope	Tier	Type
High Speed Diesel (per litre)				2.71706		2.67942	0.00072	0.03692	1	1	D
Electricity (per kWh)				0.82909					2	1	D
MIXED EMISSION FACTORS (IPCC GUIDELNES 2006 / INDIA SPECIFIC)											
FUEL/SOURCE			NCV		CO2		CH4	N2O	Scope	Tier	Type
			Tj/kt		t/Tj		t/Tj	t/Tj			
			Indian Value	IPCC	Indian Value	IPCC	IPCC	IPCC			
High Speed Diesel (Density = 0.8263 kg/Litres)			42.26 - 43.1	43.33	71.5 - 72.9	74.1	0.0039	0.0039	1	2	CS and D
			Emission Factor in terms of CO_2-e for each gas after multiplying GWP		Kg		kg	kg			
					2.49 - 2.59	2.65	0.00014	0.00014			
			Source		CO2-e (kg)				Scope	Tier	Type
Electricity (per kWh)			CO2 baseline Database for Indian Power Sector, User Guide, Ver 8.0, Central Electricity Authority, Ministry of Power, GoI, Jan 2013		0.78				2	2	CS

Calculation

The total emissions from each source is given by

Emissions = Activity Data x Emission Factor

SAMPLE CALCULATION

1. **Emissions due to electricity consumption in Samleswari OCP:**
   - **a.** Activity data for electricity consumed: **1186531 kWh**
   - **b.** Emission Factors:
     - DEFRA Emission Factor: **0.82909 kgs of CO_2-e per kWh**
     - India Specific Emission Factor: **0.78 kgs of CO_2-e per kWh**
   - **c.** Total Emissions in terms of CO_2-e:
     - DEFRA based: 1186531 x 0.82909 = **983740.99 kgs**
     - Indian Specific: 1186531 x 0.78 = **925494.18 kgs**

2. **Emissions due to fuel consumption by Excavators in Lajkura OCP:**
   - **a.** Activity data for total fuel consumed: **14446 litres of HSD**
   - **b.** Emission Factors:
     - DEFRA Emission Factor: **2.71706 kgs of CO_2-e per litre**
     - Combination of India Specific & IPCC Emission Factor : **2.55028 kgs of CO_2-e per litre**
   - **c.** Total Emissions in terms of CO_2-e:
     - DEFRA based: 14446 x 2.71706 = **39250.649 kgs**
     - Mixed: 14446 x 2.55028 = **36841.345 kgs**

Similarly the emissions from each source is calculated and the total GHG emissions for each mine is expressed in terms of CO_2-e kgs after summing up the emissions from all the sources of each mine.

The final results obtained after all calculation is presented in a tabular format in the section 5.3.

5.3 RESULTS

Samleswari OCP

Duration of Observation: 1 Month **Ore:** Coal **Monthly Production:** 927844 Te **Man Power:** 844

Table 4. Carbon Footprint of Samleswari OCP

SOURCE	EQUIPEMENT		CONSUMPTION	EMISSION FACTOR	EMISSION FACTORS				EMISSIONS				
	No.	Model		TYPE	kg CO2	kg CH4	kg N2O	kg CO2-e	kg CO2	kg CH4	kg N2O	kg CO2-e	
Electricity (kWh)			1186531	DEFRA				0.82909				983740.99	
				MIXED				0.78					925494.18
High Speed Diesel (litres)													
	DUMPERS												
	50 Te												
	2789	210M	4477										
	2790	210M	2318										
	2791	210M	3640										
	2885	210M	5558										
	2886	210M	3369										
	2923	210M	1147										
	2935	210M	6016										
	2984	210M	2425										
	3160	210M	5731										
	3161	210M	2348										
	3164	210M	4595										
		TOTAL	41624	DEFRA	2.67942	0.00072	0.03692	2.71706	111528.178 1	29.96928	1536.758	113094.91	

				MIXED	2.55	0.00014	0.00014	2.55028	106141.2	5.82736	5.82736		106152.85
	60 Te												
	3313	BH50M-1	8274										
	3333	BH50M-1	7407										
	3334	BH50M-1	9361										
	3361	BH50M-1	8693										
	3374	BH50M-1	6869										
	3380	BH50M1	2226										
	3400	BH50M-1	4926										
	3401	BH50M-1	1281										
		TOTAL	49037	DEFRA	2.67942	0.00072	0.03692	2.71706	131390.718 5	35.30664	1810.446	133236.47	
	100 Te			MIXED	2.55	0.00014	0.00014	2.55028	125044.35	6.86518	6.86518		125058.08
	1115	BH-100	4960										
	1171	BH-100	6894										
	1178	BH-100	10325										
	1179	BH-100	10637										
	10133	HD-785	13687										
	10144	HD-785	12519										
	10145	HD-785	8064										
	10146	HD-785	14638										
		TOTAL	81724	DEFRA	2.67942	0.00072	0.03692	2.71706	218972.920 1	58.84128	3017.25	222049.01	
	WATER SPRINKLER			MIXED	2.55	0.00014	0.00014	2.55028	208396.2	11.44136	11.44136		208419.08
	325	BEML	5104										
	331	BEML	3572										
	372	BEML	574										
	24048	BEML	4486										
	24049	BEML	1841										
		TOTAL	15577	DEFRA	2.67942	0.00072	0.03692	2.71706	41737.3253 4	11.21544	575.1028	42323.644	

	DOZERS			MIXED	2.55	0.00014	0.00014	2.55028	39721.35	2.18078	2.18078		39725.712
	G-10878	BD-355	6189										
	G-10798	BD-355	2812										
	G-11147	BD-355	9724										
	G-11301	BD-355	5614										
	G-11355	BD-355	10994										
	G-11736	BD-355	11301										
	103357	SD32AW	6253										
	103366	SD32AW	908										
		TOTAL	53795	DEFRA	2.67942	0.00072	0.03692	2.71706	144139.398 9	38.7324	1986.111	146164.24	
	GRADERS			MIXED	2.55	0.00014	0.00014	2.55028	137177.25	7.5313	7.5313		137192.31
	6ZJ00525	CAT 16 H	1092										
		CAT 14 M	6151										
		TOTAL	7243	DEFRA	2.67942	0.00072	0.03692	2.71706	19407.0390 6	5.21496	267.4116	19679.666	
	DRILLS			MIXED	2.55	0.00014	0.00014	2.55028	18469.65	1.01402	1.01402		18471.678
	6021116	RECP-650	3570										
	6021117	RECP-650	3820										
	6021119	RECP-650	4100										
	605635	IDM-30	5400										
		TOTAL	16890	DEFRA	2.67942	0.00072	0.03692	2.71706	45255.4038	12.1608	623.5788	45891.143	
	SHOVELS			MIXED	2.55	0.00014	0.00014	2.55028	43069.5	2.3646	2.3646		43074.229
	10007	BE-1600	19343										
	10008	BE-1600	16532										
	10088	BE-1000	18161										
	16079	BE-300	7456										
	20	SURFACE MINER	36896										
	24	SURFACE MINER	26712										

		TOTAL	125100	DEFRA	2.67942	0.00072	0.03692	2.71706	335195.442	90.072	4618.692	339904.21	
	AUXIALLA RY			MIXED	2.55	0.00014	0.00014	2.55028	319005	17.514	17.514		319040.03
	407297	RT--740 CRANE	402										
	407304	RT-880 CRANE	779										
	690	ESCORT HYDRA	208										
	RHINO-90	ACE-CRANE	250										
	B-18036	BL14TH TYRE HAND	340										
	PL-2248	WA-200	234										
		TOTAL	2213	DEFRA	2.67942	0.00072	0.03692	2.71706	5929.55646	1.59336	81.70396	6012.8538	
				MIXED	2.55	0.00014	0.00014	2.55028	5643.15	0.30982	0.30982		5643.7696
								TOTAL EMISSIONS (kg CO2-e)				2052097	1928272
				Total Emissions per ton of coal (kg CO2-e/Te)								3.36312	2.07823

LAJKURA OCP

Duration of Observation: 1 Month **Ore:** Coal **Monthly Production:** 140984 Te **Man Power:** 460

Table 5. Carbon Footprint of Lajkura OCP

SOURCE	EQUIPEMENT		CONSUMPTION	EMISSION FACTOR					EMISSIONS				
	No.	Model		TYPE	kg CO_2	kg CH_4	kg N_2O	kg CO_2-e	kg CO_2	kg CH_4	kg N_2O	kg CO_2-e	
Electricity (kWh)			**377537**	DEFRA				0.82909				313012.15	
				MIXED				0.78					294478.86
High Speed Diesel (litres)													
	DUMPERS												
	50 Te												
	2985	210M	300										
	2871	210M	3230										
	2883	210M	5025										
	2884	210M	702										
	2898	210M	355										
	2928	210M	2903										
	2933	210M	4181										
	2936	210M	3075										
	2938	210M	1013										
	2786	210M	3958										
	2932	210M	2123										
	2836	210M	846										
		Total	**27711**	DEFRA	2.67942	0.00072	0.03692	2.71706	**74249.41**	**19.95192**	**1023.09**	75292.45	
				MIXED	2.55	0.00014	0.00014	2.55028	**70663.05**	**3.87954**	**3.87954**		70670.809

	60 Te												
	60020	BH60M	4135										
	60019	BH60M	3832										
	60032	BH60M	3957										
	60031	BH60M	4570										
	3320	BH50M	6514										
	3321	BH50M	2817										
		Total	**25825**	DEFRA	2.67942	0.00072	0.03692	2.71706	**69196.02**	**18.594**	**953.459**	**70168.075**	
				MIXED	2.55	0.00014	0.00014	2.55028	**65853.75**	**3.6155**	**3.6155**		**65860.981**
	EXCAVATOR												
	55007/EXC-2579	DEMAG H55N HYD.	6710										
	55009/EXC-2580	DEMAG H55N HYD.	6781										
	G-10062/EXC-2574	BE-100 HYD.	955										
		Total	**14446**	DEFRA	2.67942	0.00072	0.03692	2.71706	**38706.9**	**10.40112**	**533.3463**	**39250.649**	
				MIXED	2.55	0.00014	0.00014	2.55028	**36837.3**	**2.02244**	**2.02244**		**36841.345**
	DRILL												
	6020815/DRC-1142	RECP-650 D	140										
	201206782/N.A.	IDM-30	250										
		Total	**390**	DEFRA	2.67942	0.00072	0.03692	2.71706	**1044.974**	**0.2808**	**14.3988**	**1059.6534**	
				MIXED	2.55	0.00014	0.00014	2.55028	**994.5**	**0.0546**	**0.0546**		**994.6092**
	DOZER												
	G-12962/T-2964	D155A-1	6778										
	G-10835/T-2186	D-355A-3	5505										
	G-11102/T-2713	D-355A-3	4646										
	G-11354/T-2865	D-355A-3	2614										
	B-10021	WHEEL DOZER	1695										

		(BD30W-1											
		Total	**21238**	DEFRA	2.67942	0.00072	0.03692	2.71706	**56905.52**	**15.29136**	**784.107**	**57704.92**	
				MIXED	2.55	0.00014	0.00014	2.55028	**54156.9**	**2.97332**	**2.97332**		**54162.847**
	GRADER												
	3184/G-390	MOTOR GRADER BG825	1515										
		Total	**1515**	DEFRA	2.67942	0.00072	0.03692	2.71706	**4059.321**	**1.0908**	**55.9338**	**4116.3459**	
				MIXED	2.55	0.00014	0.00014	2.55028	**3863.25**	**0.2121**	**0.2121**		**3863.6742**
	WATER SPRINKLER												
	370/WS-215	28KL	2216										
	371/WS-216	28KL	1800										
		Total	**4016**	DEFRA	2.67942	0.00072	0.03692	2.71706	**10760.55**	**2.89152**	**148.2707**	**10911.713**	
				MIXED	2.55	0.00014	0.00014	2.55028	**10240.8**	**0.56224**	**0.56224**		**10241.924**
	AUXILLIARY												
	11014257/MC -472	ACE RH1 NO-90C CRANE	135										
	E-26625/MC-199	ESCORT CRANE	10										
	12224/H-57	TYRE HANDLER	25										
		Total	**170**	DEFRA	2.67942	0.00072	0.03692	2.71706	**455.5014**	**0.1224**	**6.2764**	**461.9002**	
				MIXED	2.55	0.00014	0.00014	2.55028	**433.5**	**0.0238**	**0.0238**		**433.5476**
								TOTAL EMISSIONS (kg CO2-e)				**571978**	**537549**
					Total Emissions per ton of coal (kg CO2-e/Te)							**4.05704**	**3.81283**

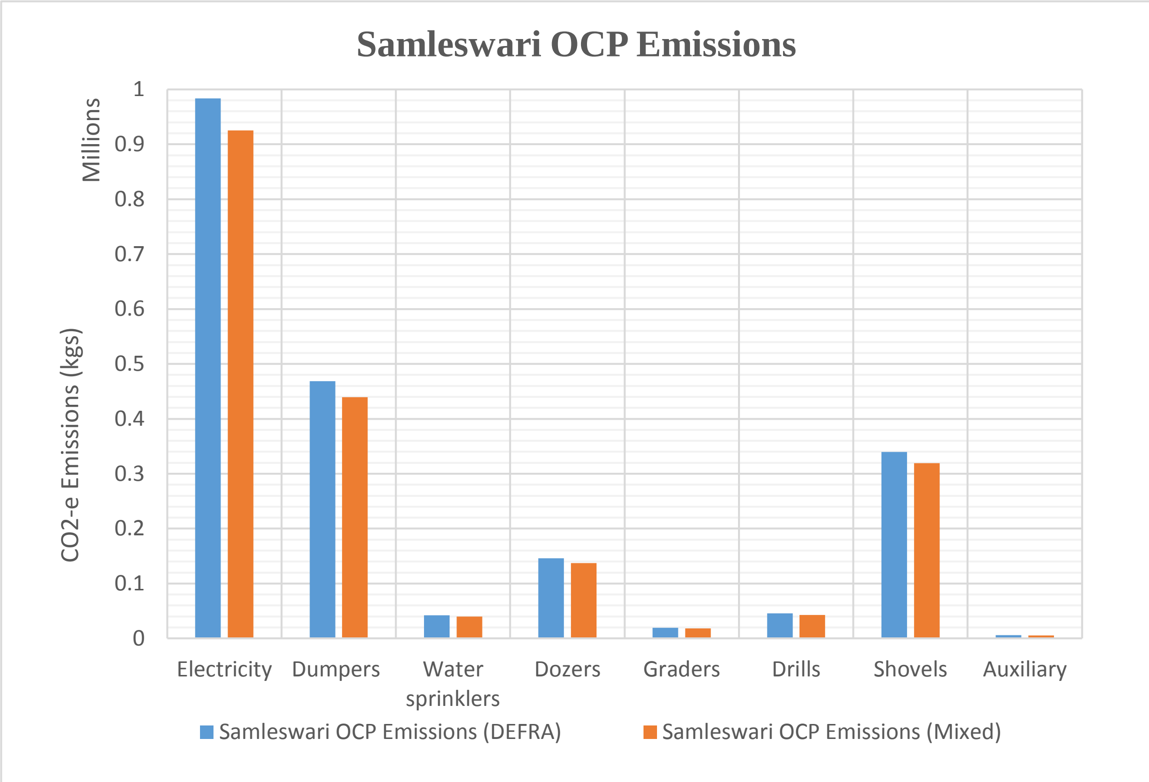


Figure 8. Samleswari OCP Emissions

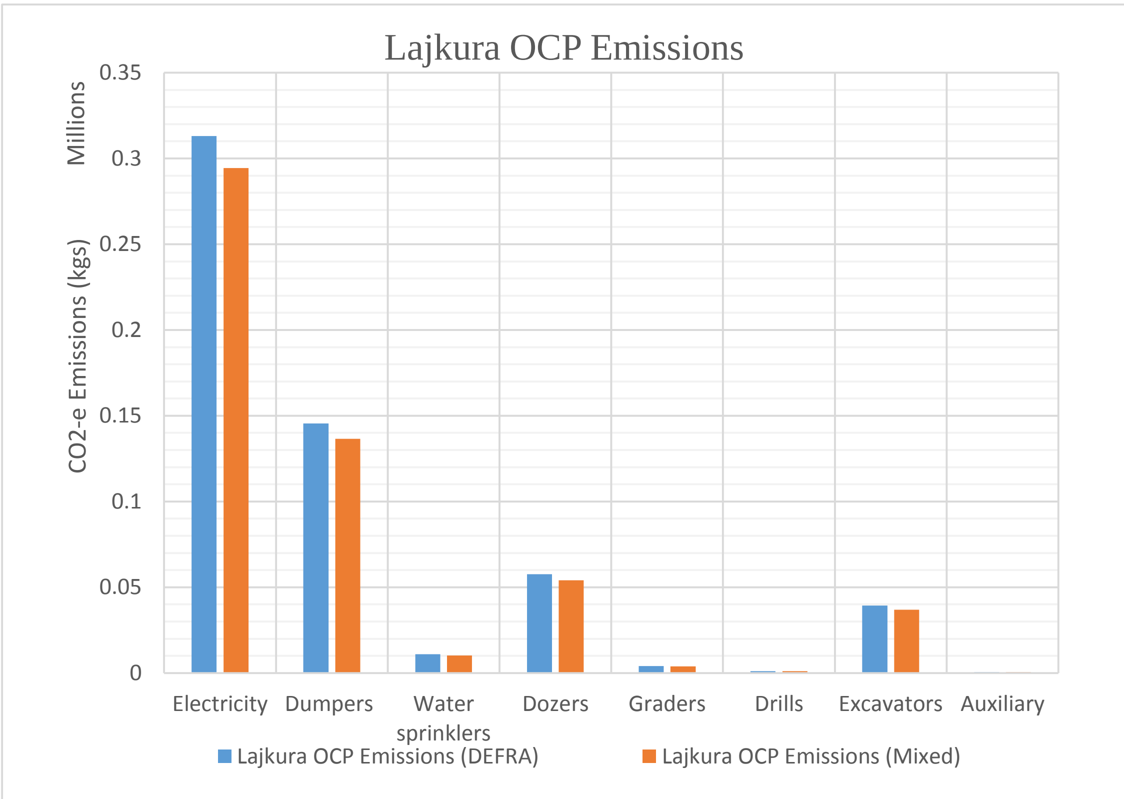


Figure 9. Lajkura OCP Emissions

5.4 DISCUSSION

The above case study presents the carbon footprint of two Indian coal mines taking into account the emissions only for two major sources – electricity consumption and fuel combustion by mining machinery. The results show that the total approximate emissions of CO_2, N_2O and CH_4 in terms of CO_2-e is found to be 2052097 kgs and 571978 kgs for Samleswari OCP and Lajkura OCP respectively, when considering the DEFRA emission factors and 1928272 kgs and 537549 kgs for Samleswari and Lajkura OCPs respectively when considering the Mixed emission factors (India specific and IPCC). The differences in results suggests the uncertainties while choosing the emission factors. Country specific emissions factor are established taking into consideration the geo-physical conditions prevalent in that country itself, thus use of country specific emission factors will provide more exactness to the emission values. Nevertheless, the results also suggest that there is not much difference in values obtained by the two different emission factors, thus if country specific emission factors are not available for any source, then default emission factors can be used to estimate the ballpark emissions.

The above estimation of approximate Carbon footprint of the mines encountered various shortcomings and problems which led to inevitable uncertainties in the results. A major ordeal faced was the unavailability of activity data, which limited our scope and boundary for the estimation. Various data relating to the use of light passenger vehicles in the mines, amount of fuel used for cooking purpose, and transportation data of the mined coals etc., which fall in the Scope 3 category and add to the GHGs emissions, were inadequate to formulate a report. Moreover, certain direct emissions such as from that of blasting are difficult to measure and thus were not included in the report. Although the emission factors used were specific to India but, it only took into account the amount of fuel consumed by the machine and not the operating condition of the machine. Thus, such discrepancies prevented the formulation of a much more exact estimation of the GHGs release by the mines.

Also, studying various case studies of the footprint report prepared certain mining companies in India, it is seen that there is no uniform methodology developed yet and thus it is difficult to compare different mines based on their carbon emissions. It is because different mining industries includes different number of sources for estimating their respective emissions. Therefore, implementing uniform methodology implies using of similar sources of emissions by all mines, so that comparison of results is possible.

Chapter 6

PROPOSED METHODOLOGIES

6.1 PROPOSED METHODOLOGY TO DEVELOP A STANDARDISED INVENTORY

Owing to the discrepancies prevailing in the current techniques of evaluation of GHG inventory by the mining companies, it is recommended to develop a suitable and more standardised methodology, so that it becomes easier for the companies to analyse their processes and also to compare different mines based on their respective carbon footprint. The main problem in the current method is that different mining industries incorporate different number of sources for their evaluation. There is no similarity in the number and type of sources each industry takes into account to estimate their GHG emissions. Thus, it becomes troublesome to find a common ground to analyse and compare these mines.

To overcome the problem, this project proposes a more standardised methodology for evaluation of emissions which delineates a particular set of sources that are compulsory for every mine to incorporate in their estimation. The emission data from each source is to be calculated using the "Activity Data" which can be collected from the company's records, registers and audit reports etc. and "Emission Factors" significant to Indian conditions.

Following the guidelines proposed in the GHG Protocol and IPCC Guidelines, this methodology categorises the required sources as following:

Scope 1

- Direct Emissions from the machineries both stationeries and mobile due to fuel combustion
- Emissions from Passenger Vehicles for Commuting within the Mines due to fuel combustion
- Fugitive Methane Emissions (for coal mines)
- Direct emissions from the processing plants

Scope 2

- Electrictiy Purchased And Consumed For
    - Offices Within The Mine Boundary
    - Machines For Mining
    - Water Pump

Scope 3

- Emissions from transport of Mined Products via Rail Or Trucks due to fuel combustion
- Emissions from the vehicles of the employees due to fuel combustion

The sources are so chosen that, are common to most of the mines and the activity data corresponding to each source are readily available with the mines. The data collected for each source must be recorded in a proper tabular format as shown in Table 6.

Table 6. Result Table Format for recording Emission data

SCOPE	SOURCE	ACTIVITY DATA (a.d) (kWh/litres/tonnes)	EMISSION FACTOR (g/unit of a.d.)	CO_2-e EMISSIONS (grams)

Each source has a particular Emission Factor corresponding to its Activity Data. For Indian conditions, the already established emission factors are:

- for emissions from Electricity consumption
- for emissions from Rail transport
- for emissions from Road transport
- for emissions as Fugitive Methane (for Coal mines)

But there is a need to develop emission factor for the emissions from the mining machineries in the Indian working conditions.

6.2 PROPOSED METHODOLOGY TO DEVELOP A STANDARDISED INVENTORY

The current emission factors used to estimate emissions from mining machineries take into account only the fuel consumed by the machineries. The emission factors are obtained by stoichiometric calculations of the fuel combustion process based on the calorific value and carbon content of the fuel used. These do not reflect the actual emissions happening due to combustion of fuel in its actual working state. It is necessary since the emission factors based on stoichiometric calculations are purely theoretical and may underestimate the actual emissions. Thus, to overcome this discrepancy, it is required to measure the actual on-site emissions of major GHG gases using gas measuring devices such as MSA multi-gas detectors etc. The measurements are to be carried out for a several number of mines and for varied type of machineries with different engine specifications, models and equipment age. The measurements for different machineries from each mine surveyed must be recorded in a particular format as given in Table 7.

Table 7. Observation Table for measuring on site emissions for different machineries

NAME OF HEMM	FUEL TYPE	MODEL	ENGG. SPECS	AGE (YEARS)	MILEAGE* (km/l)or (secs/l)	CO_2 (ppm)	N_2O (ppm)	CH_4 (ppm)	RECORDING PERIOD# (secs or km)

**for mobile machineries, Mileage = km/l and for stationery machineries, Mileage = secs/l*

#for mobile machineries Recording Period is the kms travelled and for stationery machineries it is the time in secs for which it is working

From the data collected as per the above table, the emission factor for each type of machinery of that mine can be calculated as per the following calculation:

- E_i = ppm to grams conversion
- To find the **emission factor per litre of fuel** consumed:

$$E.F_i = E_i \text{ X } M$$

Where, $E.F_i$ = emission factor for gas ‘i’

E_i = emissions in grams for gas ‘i’

M = Mileage

- To find CO_2-e

$$\text{Total } CO_2\text{-e} = \sum E.F_i \times G.W.P_i$$

Where, $G.W.P_i$ = Global warming potential of respective gas as per IPCC guidelines.

Thus collecting data for varied type of machineries from several mines and calculating emission factor of each machinery for respective mines can be used to obtain an average value of emission factor for a particular kind of machinery of a particular model, engine specification and age so that it can be used as a general Emission factor for that type of machinery used in any Indian Mines.

Chapter 7

CONCLUSION AND RECOMMENDATIONS

7.1 CONCLUSION

In context of the catastrophic rise in global temperature due to anthropogenic CO2 emissions, it is thus prima facie that the mining companies must give exclusive attention to track their GHGs emissions. Thus, to emphasize on this application, a study was conducted as a part of this project for two open-cast projects – Samleswari OCP and Lajkura OCP in the IB Valley area of Mahanadi Coalfields Ltd., a subsidiary of Coal India Ltd. Basing on the GHG Protocol and IPCC guidelines, the sources of emissions considered were emissions from combustion of fuels in mining machinery (direct sources) and consumption of electricity (indirect sources). The activity data were collected for a period of one month from the official records maintained by the mines respectively. Emission factors used were a combination of default and country-specific emission factors. The total approximate emissions of CO_2, N_2O and CH_4 in terms of CO_2-e was calculated to be 2052097 kgs and 571978 kgs for Samleswari OCP and Lajkura OCP respectively, when considering the DEFRA emission factors and 1928272 kgs and 537549 kgs for Samleswari and Lajkura OCPs respectively when considering the Mixed emission factors (India specific and IPCC). Although it gives a very rough estimate of the GHG emissions from the mines, it underestimates the actual GHG emissions from the mines as many of the other major sources of emissions are not taken into consideration due to lack of availability of activity data. Therefore, it is required that proper records of all data relating to activities which are significant to the release of GHGs are maintained properly. Moreover, a standard procedure must be adopted by all mines in India so that comparing the emissions is possible. A proposal of a uniform methodology that could be adopted by mines is presented in the previous section. Besides, accurate emission factors must be developed incorporating the mine working conditions to calculate precise emissions. Thus, a methodology to estimate the emission factors for the heavy earth moving machinery (HEMM) is also proposed in the previous section. Using that methodology emissions per unit consumption of fuel by the machinery can be obtained taking into account the working conditions of the machinery which will generate more exact results of emissions.

7.2 RECOMMENDATIONS

Mere calculation of emissions won't suffice to curtail the mounting climate change threat. Proper study of the emission results must be carried out to analyse the key sources of emissions and implement mitigation strategies either to increase the efficiency of sources to reduce the emissions or to suggest more eco-friendly alternatives to those activities. Few recommendations which can be carried out to control the GHG emissions in mines are:

- **Enhancing Carbon Sinking techniques**

  Carbon sinking refers to the absorption of CO_2 gas. It can be natural or artificial. Natural carbon sinking occurs when natural objects absorb CO_2 gas, such as forests, oceans soils etc. Artificial carbon sinking occurs when man-made technology is applied to absorb the gas such as Carbon sequestration, i.e. forcing the gas inside the earth's crusts (mostly abandoned or amenable mines). Therefore more plantation around mining area can help in carbon sinking which will result in the reduction of net emissions. Also, more research work should be carried out in carbon sequestration techniques and make it feasible for mines to use it.

- **Increase use of Solar Power**

  Emission results showed that electricity consumption is the highest contribution of GHG emissions with exceptionally high margin. Although it is an indirect source, that is, the emissions do not occur at the mine itself but at the thermal power plant where coal is burnt to produce electricity, still it is adding GHG to the atmosphere. Considering the astonishingly large amount of emissions due to power generation through conventional methods, there should be a shift towards harnessing the solar energy to meet the power demands of the mines. Since open-cast projects receive ample amount of sun's radiation throughout, and moreover, they are surrounded by large open fields (most of it are the reclaimed lands), thus numerous solar panels can be installed across the large fields to produce sufficient solar power to meet the mines requirements.

- **Regular maintenance of the mining machinery**

  Following the electricity consumption, are the emissions from the mining machinery. Although it is impossible to totally eliminate the emissions from machinery as the emissions are inevitable to the combustion of fuel, but proper maintenance of the machines ensures higher efficiency and thus lesser emissions for greater amount of work done. Regular maintenance include scheduled cleaning and repairing of machine parts especially AC element filters, carburettors, water separators in fuel tanks, air intakes etc. Use of good quality of fuel and avoid using machines with damaged or very old engines.

7.3 SCOPE FOR FUTURE STUDIES

As discussed earlier, emission factors determine the exactness of the emission values. Thus, more appropriate the emission factor, more accurate will be the emission results. In mines, the mining machinery, i.e. the Heavy Earth Moving Machinery (HEMMs) are the primary direct sources of GHG emissions. The fuel combustion that undergoes in each of these machines, liberate significant amount of GHG gases. But the present emission factors are based simply on the calorific value of the fuel and have been established on the basis of stoichiometric calculations. These do not account for the on-site working conditions of the machines as well as the surrounding geo-physical conditions. Thus, to make the emission factors of the machinery more appropriate, they must be established taking into account the working conditions of the machines. Such an attempt was made during this project, to establish the emission factor from the machinery by directly measuring the on-site emissions from those machines. But due to unavailability of proper equipment and lack of time, it could not be established. Nevertheless, a methodology is proposed, which can be used to establish emission factors for mining machinery by direct on-site measurements.

Chapter 8

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