

# CO<sub>2</sub> Emission Accounting Model in Nonferrous Mining Industry

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**Abstract.** The policy of carbon peak in 2030 address the question of how to account CO<sub>2</sub> emissions of Nonferrous Mining. The aim of this study is to establish CO<sub>2</sub> emissions accounting model, focused on usual activities, e.g. fuel combustion emission, process emission, emission from purchased and exported electricity and heat. And also to discuss explosive and urea emission sources to identify the significant process that contribute the most to climate change. Moreover, the accounting model is chosen to evaluate emissions of one mine in china, and explosive explosion and urea use of CO<sub>2</sub> emissions accounting for 4.61% and 3.97%, respectively.

**Keywords:** CO<sub>2</sub> Emission; Nonferrous Mining Industry

## 1. Introduction

Nonferrous mining industry, as a high energy consumption and high emission industrial sector, is one of the key industries to achieve the 2030 carbon peak in China [1].

In recent years, many scholars have carried out research on greenhouse gases in the Nonferrous mining and mineral industry from the aspects of carbon emission reduction, carbon peak and carbon footprint [2-4]. In 2015, “Guidelines for Accounting Methods and Reporting of Greenhouse Gas Emissions from Mining Enterprises” was issued [5]. In 2016, “General guideline of the greenhouse gas emissions accounting and reporting for industrial enterprises” was implemented [6]. Those two files build accounting models including CO<sub>2</sub> emissions from fuel combustion, process emissions, emissions from purchased electricity and heat, and emissions from exported electricity and heat. In 2019, the 2019 refinement to 2006 IPCC guidelines for national greenhouse gas inventory was adopted at the 49th IPCC plenary session. The guidelines include four aspects, such as energy, industrial process and product use, agriculture, forestry and other land use, waste [7].

The nonferrous mining industry has its own characteristics. Most of the mining machinery is diesel equipment, which involved CO<sub>2</sub> emissions caused by the use of urea. At the same time, explosive explosions produce CO<sub>2</sub>. The two emission sources are rarely mentioned. Therefore, this study, which based on four activities, including fuel combustion emission, process emission, emission from purchased and exported electricity and heat, will refine explosive and urea emission sources to identify the significant process that contribute the most to climate change. Finally, the

accounting model is chosen to evaluate emissions of one mine in China.

## 2. Source of carbon dioxide emissions

The CO<sub>2</sub> emission sources in nonferrous mines are shown in Table 1.

**Table 1.** Statement of sources and types of greenhouse gases

Accounting boundary	Greenhouse gas source	Types of greenhouse gases
Fuel combustion emission	Stationary facility or mobile facility	CO <sub>2</sub>
Process emission	Explosive explosion process	CO <sub>2</sub>
	The process of using urea for diesel vehicles	CO <sub>2</sub>
Emission from purchased electricity and heat	Purchased electricity and heat	CO <sub>2</sub>
Emissions from exported electricity and heat	Exported electricity and heat	CO <sub>2</sub>

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### 3. CO<sub>2</sub> emissions accounting model

The emissions from nonferrous mines should be estimated using Equation(1).

$$E = E_{\text{fuel}} + E_{\text{process}} + E_{\text{purchased}} + E_{\text{expoted}} \quad (1)$$

$E$ =total amount of CO<sub>2</sub> emitted due to nonferrous mine exoration activities, t CO<sub>2</sub>;

$E_{\text{fuel}}$ =CO<sub>2</sub> emissions from fuel combustion, t CO<sub>2</sub>;

$E_{\text{process}}$ =CO<sub>2</sub> emissions from process;

$E_{\text{purchased}}$ =CO<sub>2</sub> emissions from purchased electricity and heat;

$E_{\text{expoted}}$ =CO<sub>2</sub> emissions from exported electricity and heat.

#### 3.1 CO<sub>2</sub> emissions from fuel combustion

The emissions from nonferrous mines are given by Equation(2).

$$E_{\text{fuel}} = \sum_{i=1}^n (AD_i \times CC_i \times OF_i \times \frac{44}{12}) \quad (2)$$

$AD_i$ =amount of fuel combusted, t or 10<sup>4</sup>Nm<sup>3</sup>;

$CC_i$ =carbon content by type of fuel, tC/t or tC/10<sup>4</sup>Nm<sup>3</sup>;

$OF_i$ =the carbon oxidation factor by type of fuel, %;

$i$ =type of fuel.

#### 3.2 CO<sub>2</sub> emissions from process

To calculate the emissions of process, the result must be summed as equation (3).

$$E_{\text{process}} = E_{\text{industrial explosives}} + E_{\text{urea}} \quad (3)$$

$E_{\text{industrial explosives}}$ =CO<sub>2</sub> emissions from industrial explosive explosion in mine production;

$E_{\text{urea}}$ =CO<sub>2</sub> emissions from urea for diesel vehicle.

##### 3.2.1 CO<sub>2</sub> emissions from industrial explosive

There are three kinds of explosives commonly used in mining enterprises, namely emulsion explosives, ammonium oil explosives and powdery ammonium nitrate explosives. In 2021, the total output of industrial explosives was 4.4151 million tons, of which ammonium oil explosives accounted for 22.67%, emulsion explosives 67.36%, ammonium nitrate explosives 7.91%, and others 2.06%.

When the explosive explodes, CO<sub>2</sub>, CO, NO, NO<sub>2</sub>, N<sub>2</sub>O<sub>3</sub>, HCl, H<sub>2</sub>S and a small amount of other toxic gases are generated. Gases of five kinds of explosives is shown in table 2[8].

Table 2. Gas composition of five explosive

Name	Gas composition %					subtotal
	CO <sub>2</sub>	C O	H <sub>2</sub>	N <sub>2</sub>	NO <sub>x</sub>	
1 # ammonium antimony explosive	31.5	2.9	2.6	63.1	0.063	100.16
2# ammonium antimony explosive	29	0	0.3	63.7	2.19	95.19
Hw-1 explosive	28.1	1.8	3.0	65.2	0.027	98.13
Hw-2 explosive	27.8	3.3	3.8	64.6	1.02	100.52
Anfo explosive	22.6	1.7	3.4	68.2	0.09	95.99

Carbon in explosives is oxidized to CO<sub>2</sub> after one and two reactions. As long as the chemical formula of explosives is written, CO<sub>2</sub> emissions can be calculated by carbon element, which is named carbon balance calculation method. There are two main estimation methods.

Firstly, if the carbon content of explosives is known, Estimation of CO<sub>2</sub> emission factors for explosive explosions is shown by equation (4).

$$EF_{\text{industrial explosives}} = C \times \eta \times \frac{44}{12} \quad (4)$$

$EF_{\text{industrial explosives}}$ =emission factor of industrial explosives, tCO<sub>2</sub> per explosives;

$C$ =Carbon content in mixed explosives, %;

$\eta$ =Percentage of carbon converted to carbon dioxide gas. The values should be based on the monitoring data of different explosives, and the default value can be 100 %;

The second, if the chemical formula in explosives and its corresponding mass fraction are provided, Estimation of CO<sub>2</sub> emission factors for explosive explosions is shown by equation (5).

Explosives are a mixture. If the chemical formula of each material composition is  $C_{a_i}H_{b_i}N_{c_i}O_{d_i}$  and the proportion of each component is  $\beta_i$ , so  $\sum_{i=1}^n \beta_i = 1$ .

$$EF_{\text{industrial explosives}} = \sum_{i=1}^n \frac{44\beta_i a_i}{12a_i + b_i + 14c_i + 16d_i} \times \eta \quad (5)$$

$i$ = material composition iof explosives;

$\beta_i$ =mass fraction, %;

$\eta$ = Percentage of carbon converted to carbon dioxide gas. The values should be based on the monitoring data of different explosives, and the default value can be 100 %;

Equation 6 should be used to estimate the amount of CO<sub>2</sub> emitted from explosion.

$$E_{\text{industrial explosives}} = \sum_{i=1}^n AD_{\text{industrial explosives}, i} \times EF_{\text{industrial explosives}, i} \quad (6)$$

$E_{\text{industrial explosives}}$ =emissions of industrial explosives, tCO<sub>2</sub>;

$AD_{\text{industrial explosives},i}$ =amount of industrial explosives consumed, t;

$EF_{\text{industrial explosives},i}$ =emission factor for industrial explosives i, t CO<sub>2</sub> per ton of industrial explosives;  
*i*=industrial explosives.

### 3.2.2 CO<sub>2</sub> emissions from urea

CO<sub>2</sub> emissions from urea are calculated using equation (7).

$$E_{\text{urea}} = \sum_{i=1}^n AD \times EF \times P \times \eta \quad (7)$$

$E_{\text{urea}}$ =emissions of urea, tCO<sub>2</sub>;

$AD_i$ =amount of urea consumed, t;

$EF$ =emission factor for urea, tCO<sub>2</sub> per ton urea, 0.7333[9];

$P$ =Urea concentration in urea solution, %, 32.5%[9];

$\eta$ =Decomposition rate of urea; The values should be based on the monitoring data of different diesel vehicle, and the default value can be 100 %.

### 3.3 CO<sub>2</sub> emissions from purchased electricity and heat

The emissions from purchased electricity and heat should be estimated using Equation(8).

$$E_{\text{purchased}} = E_{\text{purchased electricity}} + E_{\text{purchased heat}} = AD_{\text{electricity}} \times EF_{\text{electricity}} + AD_{\text{heat}} \times EF_{\text{heat}} \quad (8)$$

$E_{\text{purchased}}$ =CO<sub>2</sub> emissions from purchased electricity and heat;

$E_{\text{purchased electricity}}$ =CO<sub>2</sub> emissions from purchased electricity;

$E_{\text{purchased heat}}$ =CO<sub>2</sub> emissions from purchased heat;

$AD_{\text{electricity}}$ = the amount of purchased electricity;

$AD_{\text{heat}}$ = the amount of purchased heat;

$EF_{\text{electricity}}$ =annual average carbon dioxide emission factor of regional power grid;

$EF_{\text{heat}}$ = emission factor for heat.

### 3.4 CO<sub>2</sub> emissions from exported electricity and heat

The emissions from exported electricity and heat should be estimated using Equation(9).

$$E_{\text{exported}} = E_{\text{exported electricity}} + E_{\text{exported heat}} = AD_{\text{electricity}} \times EF_{\text{electricity}} + AD_{\text{heat}} \times EF_{\text{heat}} \quad (9)$$

$E_{\text{exported}}$ =CO<sub>2</sub> emissions from exported electricity and heat;

$E_{\text{exported electricity}}$ =CO<sub>2</sub> emissions from exported electricity;

$E_{\text{exported heat}}$ =CO<sub>2</sub> emissions from exported heat;

$AD_{\text{electricity}}$ = the amount of exported electricity;

$AD_{\text{heat}}$ = the amount of exported heat;

$EF_{\text{electricity}}$ =annual average carbon dioxide emission factor of regional power grid;

$EF_{\text{heat}}$ = emission factor for heat.

## 4. Data and Results

The accounting model is developed on one open-pit mine in China. Ore and rock is transported by diesel vehicle using urea. And ammonium oil explosives should be used in mine. All data are provided by the enterprise. The CO<sub>2</sub> emission are shown in Table 3.

The annual carbon emission is as high as 54382.57 t, and power consumption is the main source of carbon emission, accounting for 57.59 % of total carbon emission. Process emissions, which includes explosive explosion and urea use, are also important components of greenhouse gases, accounting for 4.61% and 3.97%, respectively.

**Table 3.** CO<sub>2</sub> emissions from one open-pit mine

source		Emissions, t per year	%
fuel combustion emission		18398.97	33.83
process emission	Explosive explosion process	2508.32	4.61
	The process of using urea	2158.68	3.97
purchased electricity		31316.6	57.59
total		54382.57	100

## 5. Discussion

Fuel combustion caused by transportation is one of the main source of carbon emissions, but transportation is usually commissioned and may not be included in statistics. Therefore, it is suggested that CO<sub>2</sub> emissions within the geographical boundaries should be included in the accounting scope.

CO<sub>2</sub> emissions of explosive explosion and urea use is an important source, which should be included in the CO<sub>2</sub> emission accounting model of Nonferrous Mining Industry.

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