Calculation method of CO_2 emission of thermal power plant in China

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Abstract. With the proposal of carbon dioxide peak in 2030 and carbon dioxide neutrality by 2060, more and more concern are shown in fossil fuel power plants. Since coal-fired power plant takes more than 90% in China of the power supplying side, discussion of how the CO_2 trading quota is calculated and how to confirm the amount of CO_2 seem emergency in CO_2 neutrality area. This paper introduced the calculation method of CO_2 trading quota and actual emission amount from the government document and present a calculation example with the operation data from a 300MW coal-fired power plant for reference.

Keywords: CO_2, Carbon Dioxide Emission, Coal-fired Power Plant.

1. Background

On September 22th, 2020, President Xi Jinping announced at the 75th United Nations General Assembly for the first time: China will adopt more powerful policies and measures, strive to reach the peak of carbon dioxide emissions by 2030, and strive to achieve carbon dioxide neutrality by 2060. At the end of 2020, Ministry of Ecology and Environment of the People's Republic of China issued *"2019-2020 National CO_2 Emissions Trading Quota Setting and Distribution Implementation Plan (Power Generation Industry)"*[1]and *"Guidelines for Accounting Methods and Reporting of Corporate Greenhouse Gas Emissions"*[2]. The CO_2 emission quota is released by the government while the greenhouse gas emission is based on the actual fossil fuel consumptions.

This article will introduce how the CO_2 quota is considered by the government and the method of calculating the actual CO_2 emission of coal-fired power plant in China.

2. CO_2 Trading Quota

On December 30th, 2020, Ministry of Ecology and Environment of the People's Republic of China issued the document of *"2019-2020 National CO_2 Emissions Trading Quota Setting and Distribution Implementation Plan (Power Generation Industry)".*In the power generation field, including industrial power plant, the annual CO_2 emission above 26,000 ton of any year of 2013 to 2019 (the equivalent energy consumption is about 10,000 tons of standard coal) shall be on the Key Emission List and there are 4 kinds of power units of which CO_2 emission trading quota will be managed by the government,which is shown in Table 1.

Table 1. Power Units Categories included in the management of CO_2 Quota

Categories	Requirement
Conventional coal-fired units above 300MW	Power units with bituminous coal, lignite and anthracite as main fuel and at the same time rated power not below 400MW
Conventional coal-fired units above 300MW	Power units with bituminous coal, lignite and anthracite as main fuel and at the same time rated power below 400MW
Unconventional coal-fired units such as coal gangue, coal slime, coal water slurry, etc.(Including Circulating Fluidized Bed Boiler)	Unconventional coal-fired units such as coal gangue, coal slime, coal water slurry, etc.(Including Circulating Fluidized Bed Boiler) and in a full performance year, the average annual unconventional fuel heat takes a part more than 50%
Gas Unit	Gas unit which use gas as main fuel and the average annual mixed fuel heat takes no more than 10%

2.1. CO_2 Quota calculation

The CO_2 quota is calculated as follows:

$$A = A_e + A_h$$

In which, *A* is the total CO_2 emission trading quota of power unit, t CO_2.

A_e is the CO_2 emission trading quota from power supplied out, t CO_2.

A_h is the CO_2 emission trading quota from heat supplied out, t CO_2.

$$A_e = Q_e \times B_e \times F_L \times F_r \times F_f$$

I_n which,Q_e is the power supplied out by the Unit, MW.

B_e is the CO_2 emission reference value of power supplied by the power generation unit, t CO_2/MWh.

F_l is the Unit cooling method correction factor. For the water cooled-condensers F_l is 1 while air-cooled of 1.05.

F_r is the heat supply correction factor. For coal-fired power plant it is 1-0.22×α (α is heating ratio).

F_f is the Unit Load correction factor.

$$A_h = Q_h \times B_h$$

In which, Q_h is the heat supplied by the Unit, GJ.

B_h is the the CO_2 emission reference value of heat supplied by the power generation unit, t CO_2/GJ.

2.2. The calculation of heating ratio α

The factor F_r shall be calculated from the heating ratio and for the coal-fired power plant there are 3 conditions.

(1) No direct heat supply from the boiler

$$\alpha = \frac{Q_{jz}}{Q_{sr}}$$

In which, α is the heating ration,%.

Q_{jz} is the total heat supplied from boiler including direct and indirect heat exchange, GJ.

Q_{sr} is the total heat consumed by the steam turbine, GJ.

(2) Direct heat supply from the boiler

$$\alpha = \frac{Q_{gr}}{Q_{cr}}$$

In which, Q_{gr} is the total heat supplied from boiler, GJ.

Q_{cr} is the total heat generated by boiler (the main steam enthaphy minus feed water enthaphy), GJ.

(3) The relative data in condition (1) and (2) is unavailable

$$\alpha = \frac{b_r \times Q_{gr}}{B_h}$$

In which b_r is capital standard coal consuming per heat supplied by Unit, tce/GJ.

Q_{gr} is the total heat supplied out by the Unit, GJ.

B_h is the total standard coal consumed by Unit, tce.

2.3. The Unit Load Correction Factor F_f

The document*"2019-2020 National CO_2 Emissions Trading Quota Setting and Distribution Implementation Plan (Power Generation Industry)"* has taken reference from *"The norm of energy consumption per unit product of general coal-fired power set (GB21258-2017)"*[3].

The recommended unit load correction factor of conventional coal-fired condensate power generation set is shown in Table 2.

Table 2. Recommended Unit Load Correction Factor

Unit Load Factor "F" in statistical period, %	Unit Load Correction Factor
F≥85%	1
80%≤F≤85%	1+0.0014×(85-100F)
75%≤F＜80%	1.007+0.0016×(80-100F)
F＜75%	$1.015^{(16-20F)}$

The Unit Load Factor is calculated as follows:

$$F = \frac{\sum_i^n W_{fdi}}{\sum_i^n P_{ei} \times t_i}$$

In which, W_{fd} is the power generated by power generation sets, MWh.

P_e is the rated power of power generation sets, MW.

t is the operation hours (equivalent hours at full load) of power generation sets, h.

i is the power generation unit code.

2.4. The CO_2 Emission Reference Value B_e and B_h

The government has recommended reference value of capital CO_2 emission, which is shown in Table 3, for power plants in different scale.

Table 3. CO_2 Emission Reference Value

Categories	CO_2 Emission Reference Value of Power Supplied by Generation Sets,Be (t CO_2/MWh)	CO_2 Emission Reference Value of Heat Supplied by Generation Sets,Bh (t CO_2/GJ)
Conventional coal-fired units above 300MW	0.877	0.126
Conventional coal-fired units above 300MW	0.979	0.126
Unconventional coal-fired units such as coal gangue, coal slime, coal water slurry, etc.(Including Circulating Fluidized Bed Boiler)	1.146	0.126
Gas Unit	0.392	0.059

3. Actual CO_2 Emission Calculation

In *"Guidelines for Accounting Methods and Reporting of Corporate Greenhouse Gas Emissions",* CO_2 emission calculation procedures and methods are introduced.

3.1. Procedures

CO_2 emission calculation of power generation sets includes determination of accounting boundaries and emission sources, data quality control plan preparation, fossil fuel combustion emission accounting, purchased electricity emission accounting, emission calculation, production data acquisition, regular reports, information disclosure and data quality management[4].

Figure 1 shows the logic relations of above procedures.

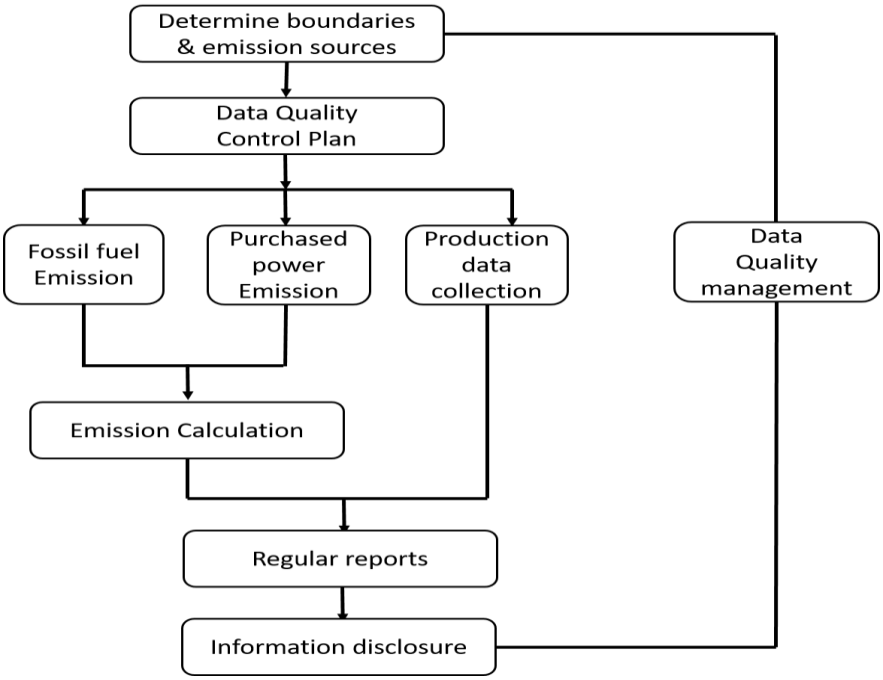

Figure 1. CO_2 emission management procedures

The scope of the calculation and reporting of CO_2 emissions from power generation facilities includes: CO_2 emissions from the burning of fossil fuels, purchase and use of electricity.

CO_2 emissions from fossil fuel combustion generally include boilers for power generation (including start-up boilers), gas turbines, etc., the burning of fossil fuels consumed by the production system, excluding emergency diesel generator sets, mobile sources, canteens, etc. For biomass power generating sets that blend with fossil fuels, waste incineration power generating sets, etc., only the fossil fuels are counted.

3.2. CO_2 emission calculation

CO_2 emission amount shall be the sum of CO_2 emission from fossil fuel combustion and power purchased.

$$E = E_{burn} + E_{power}$$

In which, E is the total amount of CO_2 discharged by the power generation sets, t CO_2.

E_{burn} is the amount of CO_2 discharged from fossil fuel combustion, t CO_2.

E_{power} is the amount of CO_2 discharged from power purchased, t CO_2.

3.2.1 Calculation of E_{burn}

$$E_{burn} = \sum_{i=1}^{n} (AD_i \times EF_i)$$

In which, AD_i is the activity data of fossil fuel i, GJ.

EF_i is the CO_2 emission factor of fossil fuel i, t CO_2/GJ.

$$AD_i = FC_i \times NCV_i$$

In which, FC_i is the consumption of fossil fuel i, t.

NCV_i is the net calorific value of fossil fuel i, GJ/t.

While for the CO_2 emission factor it can be calculated as follows:

$$EF_i = CC_i \times OF_i \times \frac{44}{12}$$

In which, CC_i is the carbon content per calorific value of fossil fuel *i*.

OF_i is the carbon oxidation rate of fossil fuel, %.

For all kinds of coal, OF_i is assumed as 99% in *"Guidelines for Accounting Methods and Reporting of Corporate Greenhouse Gas Emissions"*.

For the specific fossil fuel, such as coal, the carbon content per calorific value is calculated as :

$$CC_{coal} = \frac{C_{coal}}{NCV_{coal}}$$

In which, C_{coal} is the carbon content in the fuel, tC/t.

NCV_{coal} is the net calorific value of coal at received basis, GJ/t.

NCV_{coal} should be from daily coal test data according to GB/T 213 *"Determination of calorific value of coal"* before entering boiler in priority. If it is not available, the daily or each batch of coal test data before entering plant could be used. 26.7GJ/t shall be used as NCV_{coal} if the above data is unavailable or the test method is not compliant with the standard.

C_{coal} shall also be from the daily coal test data before entering boiler. If it is not available at some period, the value shall be 0.03356 tC/GJ for all kinds of coal.

3.2.2 Calculation of E_{power}

$$E_{power} = AD_p \times EF_p$$

In which, AD_p is power purchased from national grid, MWh.

EF_p is the national grid emission factor, tCO_2/MWh.

EF_p shall be 0.6101 tCO_2/MWh or the latest value issued by Ministry of Ecology and Environment of the People's Republic of China.

3.3. Diesel

Since diesel is the common support fuel for coal-fired plant in low load, *"Guidelines for Accounting Methods and Reporting of Corporate Greenhouse Gas Emissions"* has provided the net calorific value of diesel *"NCV"* as 42.652GJ/t and the carbon content per heat *"CC"* of 0.0202 TC/GJ. The carbon oxidation rate *"OF"* is of 98%.

4. CO_2 Emission Calculation Example

In this chapter the real operation data from a 300MW coal-fired plant is collected and the total CO_2 emission amount is calculated.

The operation data is shown in Table 4.

Table 4. Operation Data from a 300MW coal-fired Power Plant

operation data				
Unit Capacity	Cooling Type	Average Coal NCV MJ/kg (received basis)	Average Carbon content % (received basis)	Annual Coal Consumption (ton)
300	water-cooled	19.019	49.75	775121.8
Annual Diesel Consumption(ton)	Power Puchased(MWh)	Annual Power Supplied (MWh)	Annual Heat Supplied (GJ)	Diesel NCV (GJ/t)
165.23	1000	1444671.3	96548.92	42.652

According to *"2019-2020 National CO_2 Emissions Trading Quota Setting and Distribution Implementation Plan (Power Generation Industry)"*, the CO_2 emission trading quota of this power plant is calculated as 1286689 tons. The results is introduced in Table 5.

Table 5. CO_2 emission trading quota

Power Supplied (MWh)	Co_2 Emission Reference Value Of Power Supplied (tCO_2/MWh)	Unit Cooling Method Correction Factor	Heat Supply Correction Factor	Unit Load Factor	Unit Load Correction Factor	co_2 Emission from Power (tons of co_2)
1444671.3	0.979	1	0.84	0.58	1.07	1274524
Heat Supplied (GJ)	Co_2 Emission Reference Value Of Heat Supplied (tCO_2/GJ)	Co_2 Emission From Heat (tons of CO_2)	Total Co_2 Emission (tons of CO_2)			
96548.92	0.126	12165.2	1286689			

The actual CO_2 emission calculation results are shown in Table 6.

Table 6. CO_2 Emission Calculation Results

Calculation Results						
Coal Activity Data (GJ)	Diesel Activity Data (GJ)	Coal Carbon Content Per Heat Value (tC/GJ)	Diesel Carbon Content Per Heat Value (tC/GJ)	Coal Carbon Oxidation Rate %	Diesel Carbon Oxidation Rate %	
14742042	7047	0.026	0.0202	99%	98%	
Coal Co_2 Emission Factor (tCO_2/GJ)	Diesel Co_2 Emission Factor (tCO_2/GJ)	National Grid Co_2 Emission Factor (tCO_2/MWh)	CO_2 Emission From Power Purchased (ton)	Co_2 Emission From Coal Combustion (ton)	CO_2 Emission from Diesel Combustion (ton)	Total CO_2 Emission (tons of CO_2)
0.095	0.0726	0.6101	610.1	1399811.8	511.5	1400933

The permitted CO_2 emission amount is not enough for this power plant and the gap of 114424 tons of CO_2 shall be considered by trading or other solutions.

5. Conclusion

This paper introduced the calculation method of coal-fired power plant CO_2 emission quota and the actual emission amount. The method is from government documents *"2019-2020 National CO_2 Emissions Trading Quota Setting and Distribution Implementation Plan (Power Generation Industry)"*and *"Guidelines for Accounting Methods and Reporting of Corporate Greenhouse Gas Emissions".* In this paper the real data from a 300MW coal-fired power plant reflected that there should be more attention [5] to be paid on plant efficiency in case the CO_2 quota is not enough. And it is essential for the power plant to make detailed record for the coal data before entering boiler and get the real-time emission value so they can prepare good strategies for the CO_2 trading.

References

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