Environmental Costs and Performance Measurement Research Based on EMA in China

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Abstract: Traditional Financial Cost Accounting ignores the existence of environmental costs, and does not consider the environmental pollution caused by production activities. The paper focuses on environmental costs and performance measurement based on EMA in China. On the analysis of material flow system in enterprise manufacturing process, material flow measurement model has been constructed.Input-output table in enterprise manufacturing process has been designed, based on the material flow balance. Measurement models of environmental costs and environmental performance have been discussed in accordance with material flow mass balance equation.EC Iron and Steel Co. Ltd. in Hubei province has been taken as an example of empirical research.The research findings suggest that measurement of environmental costs and environmental performance in the business activities of enterprises would contribute to the evaluation of impact on natural environment, and would objectively reflect the actual value of production activities.

Keywords: Material Flow Cost Accounting; Environmental Costs; Environmental Performance; Measurement Model

1 Introduction

China is one of the fastest growing economies in the world.With the rapid economic development,environmental issues are also increasingly prominent. Environmental degradation restricts the sustainable development in China.

The United Nations Division for Sustainable Development (UNDSD) emphasized that,"Management accounting is concerned with providing information to organization for internal calculation and decision. Environmental accounting procedures for internal decision-making include material and energy consumption, flow and final processing procedure,and monetization program of input and output related with potential environmental impacts."

How to build the new measurement model of environmental costs and performance based on Environmental Management Accounting in China?

Traditional Financial Cost Accounting does not consider the environmental pollution caused by production activities. It ignores the existence of environmental costs, and transfers the whole cost to the product cost account. It needs to search for new methodologies based on Environmental Management Accounting to evaluate environmental costs and performance.

As an important part of Environmental Management Accounting, Material Flow Cost Accounting (MFCA) tracks and controls the overall material input by analysing material flow in the business process of enterprise, reduces environmental impact and cost by analysing the causes of waste generated in the production process. In order to coordinate development of environment and economy, MFCA can improve the management in production, reduce the emissions of waste, and increase productivity in enterprises.

2 Analysis of Material Flow System in Enterprise Manufacturing Process Based on MFCA

The core theory of MFCA is the material flow analysis theory,it believes that the impacts of human activities on the natural environment depends largely on the quality and quantity of natural substances inputted in the socio-economic system, and the waste emissions discharged from socio-economic system into the natural environment. The former impacts on environment, and causes environmental quality deterioration or degradation.The latter pollutes the environment directly,and causes environmental damage. Material flow analysis tracks the conditions of natural substance flow in the whole process; the process includes mining, refining, processing, production, use, recycling and disposal.It follows the law of conservation of mass, and takes the quality of the material putted in the economic system as the research object.The material in the economic system is divided into three sections, including input section, manufacturing section and output section.By studying the relationship between the three sections, it can reveal the characteristics of material flow and conversion efficiency in a specific area.

The research object of MFCA is the whole and flowing material putted in enterprise manufacturing process, and expressed in mass units and currency units.Through the effective application of the material flow system, MFCA can clearly demonstrate production, recycling and other operations in the manufacturing process of enterprises, and can reflect the material input, storage, use, conversion and output in the entire flow process, as shown in Fig. 1.

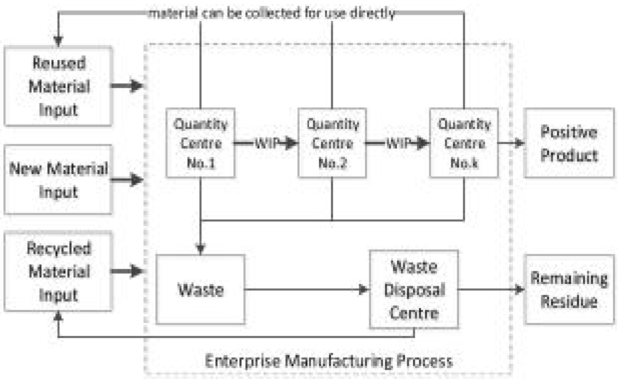

Fig.1 Material Flow System in Enterprise Manufacturing Process Based on MFCA

In this system, the material inputs mainly consist of three parts, including reused material input, new material input and recycled material input. Reused material refers to the material can be reused directly, and it was collected in the last production cycle.New material refers to the new input of resource needed for manufacturing.Recycled material was provided by the waste disposal centre in the last production cycle, it was recycled from waste which is generated by quantity centres.

There are two categories of centres in enterprise manufacturing process, quantity centre and waste disposal centre. Quantity centres are formed by the division of production process;typical quantity centre categories include storage centres, production centres, shipping centres, etc.Each category may have more than one centre. Each quantity centre deals with inputted materials, and generates WIP for the next manufacturing step or final products and waste.Waste disposal centre handles waste generated from quantity centres, and yields recycled material and remaining residue.

MFCA believes that, materials which constitute target products in enterprise are called positive products; materials which not constitute target products are considered as loss in enterprise manufacturing process, and regarded as negative products or waste. After handling by waste disposal centre, negative products generated in quantity centres are processed into recycled material which can be inputted in the next production cycle, and remaining residue which contains waste gas, waste water and solid waste.

3 Construction of Environmental Costs Measurement Model Based on the Material Flow Balance

3.1 Construction of Material Flow Measurement Model in Enterprise Manufacturing Process

According to the condition of material flow and conversion, material flow measurement model can be constructed in enterprise manufacturing process, as shown in Fig. 2.This model represents the situation of material input and output in the period of Δt.It follows the law of conservation of mass. Although the physical form of material will change in the process of input, conversion and output within a given period, the identical equation,“material input =material output”, remains unchanged.

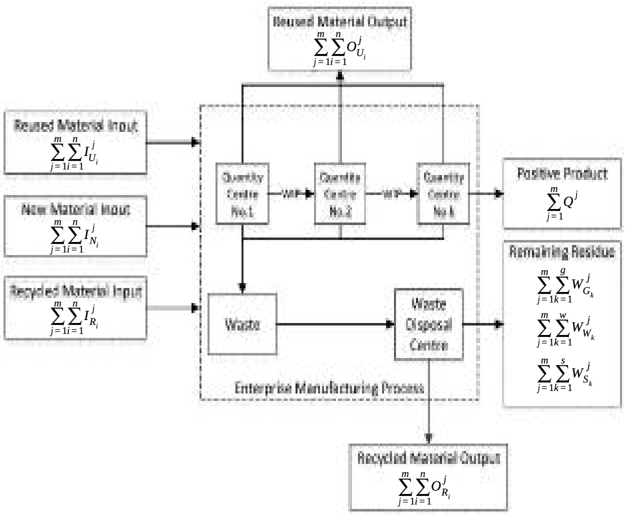

Fig.2 Material Flow Measurement Model in Enterprise Manufacturing Process

The meanings of the variables in the model are as follows:

$\sum_{j=1}^{m}\sum_{i=1}^{n} I_{U_i}^{j}$ is the total mass of reused material input in the period of Δt, and it was collected in the last production cycle. $I_{U_i}^{j}$ is the total mass ofcategory No.i reused material input which is putted into No. j product, there are n major types of material categories and m major types of products.

$\sum_{j=1}^{m}\sum_{i=1}^{n} I_{N_i}^{j}$ is the total mass of new material input in the period of Δt. $I_{N_i}^{j}$ is the total mass of category No.i new material input which is putted into No. j product, there are n major types of material categories and m major types of products.

$\sum_{j=1}^{m}\sum_{i=1}^{n} I_{R_i}^{j}$ is the total mass of recycled material input in the period of Δt, recycled material was provided by the waste disposal centre in the last production cycle. $I_{R_i}^{j}$ is the total mass of category No.irecycled material input which is putted into No. j product, there are n major types of material categories and m major types of products.

$\sum_{j=1}^{m} Q^{j}$ is the total mass of positive products in the period of Δt. Q^{j} is the total mass of No. j product, there are m major types of products.

$\sum_{j=1}^{m}\sum_{i=1}^{n} O_{U_i}^{j}$ is the total mass of reused material output in the period of Δt. $O_{U_i}^{j}$ is the total mass of category No.i reused material output which is collected in the production of No. j product, there are n major types of material categories and m major types of products.

$\sum_{j=1}^{m}\sum_{i=1}^{n} O_{R_i}^{j}$ is the total mass of recycled material output in the period of Δt. $O_{R_i}^{j}$ is the total mass of category No.i recycled material output which is provided by waste disposal centre in the production of No. j product, there are n major types of material categories and m major types of products.

$\sum_{j=1}^{m}\sum_{k=1}^{g} W_{G_k}^{j}$ is the total mass of waste gas in remaining residue, residual gas is exhausted by waste disposal centre after waste disposal in the period of Δt. $W_{G_k}^{j}$ is the total mass of category No.k waste gas which is exhausted in the production of No. j product, there are g major types of waste gas categories.

$\sum_{j=1}^{m}\sum_{k=1}^{w} W_{W_k}^{j}$ is the total mass ofwaste water in remaining residue, residual water is exhausted by waste disposal centre after waste disposal in the period of Δt. $W_{W_k}^{j}$ is the total mass of category No.k waste water which is exhausted in the production of No. j product, there are w major types of waste water categories.

$\sum_{j=1}^{m}\sum_{k=1}^{s} W_{S_k}^{j}$ is the total mass of solid waste in remaining residue, residual solid waste is exhausted by waste disposal centre after waste disposal in the period of Δt. $W_{S_k}^{j}$ is the total mass of category No.k solid waste which is exhausted in the production of No. j product, there are s major types of solid waste categories.

3.2 Construction of Input-Output Table in Enterprise Manufacturing Process Based on the Material Flow Balance

By analysing the relationship between material input flow and output flow in the manufacturing process of par-

Table 1. Input-Output Table in Enterprise Manufacturing Process Based on the Material Flow Balance

No.	Input			Output					
	Reused Material Input	New Material Input	Recycled Material Input	Positive Product	Reused Material Output	Recycled Material Output	Remaining Residue		
							Waste Gas	Waste Water	Solid Waste
1	$\sum_{i=1}^{n} I_{U_i}^{1}$	$\sum_{i=1}^{n} I_{N_i}^{1}$	$\sum_{i=1}^{n} I_{R_i}^{1}$	Q^{1}	$\sum_{i=1}^{n} O_{U_i}^{1}$	$\sum_{i=1}^{n} O_{R_i}^{1}$	$\sum_{k=1}^{g} W_{G_k}^{1}$	$\sum_{k=1}^{w} W_{W_k}^{1}$	$\sum_{k=1}^{s} W_{S_k}^{1}$
2	$\sum_{i=1}^{n} I_{U_i}^{2}$	$\sum_{i=1}^{n} I_{N_i}^{2}$	$\sum_{i=1}^{n} I_{R_i}^{2}$	Q^{2}	$\sum_{i=1}^{n} O_{U_i}^{2}$	$\sum_{i=1}^{n} O_{R_i}^{2}$	$\sum_{k=1}^{g} W_{G_k}^{2}$	$\sum_{k=1}^{w} W_{W_k}^{2}$	$\sum_{k=1}^{s} W_{S_k}^{2}$
…	…	…	…	…	…	…	…	…	…
j	$\sum_{i=1}^{n} I_{U_i}^{j}$	$\sum_{i=1}^{n} I_{N_i}^{j}$	$\sum_{i=1}^{n} I_{R_i}^{j}$	Q^{j}	$\sum_{i=1}^{n} O_{U_i}^{j}$	$\sum_{i=1}^{n} O_{R_i}^{j}$	$\sum_{k=1}^{g} W_{G_k}^{j}$	$\sum_{k=1}^{w} W_{W_k}^{j}$	$\sum_{k=1}^{s} W_{S_k}^{j}$
…	…	…	…	…	…	…	…	…	…
m	$\sum_{i=1}^{n} I_{U_i}^{m}$	$\sum_{i=1}^{n} I_{N_i}^{m}$	$\sum_{i=1}^{n} I_{R_i}^{m}$	Q^{m}	$\sum_{i=1}^{n} O_{U_i}^{m}$	$\sum_{i=1}^{n} O_{R_i}^{m}$	$\sum_{k=1}^{g} W_{G_k}^{m}$	$\sum_{k=1}^{w} W_{W_k}^{m}$	$\sum_{k=1}^{s} W_{S_k}^{m}$
Total	$\sum_{j=1}^{m}\sum_{i=1}^{n} I_{U_i}^{j}$	$\sum_{j=1}^{m}\sum_{i=1}^{n} I_{N_i}^{j}$	$\sum_{j=1}^{m}\sum_{i=1}^{n} I_{R_i}^{j}$	$\sum_{j=1}^{m} Q^{j}$	$\sum_{j=1}^{m}\sum_{i=1}^{n} O_{U_i}^{j}$	$\sum_{j=1}^{m}\sum_{i=1}^{n} O_{R_i}^{j}$	$\sum_{j=1}^{m}\sum_{k=1}^{g} W_{G_k}^{j}$	$\sum_{j=1}^{m}\sum_{k=1}^{w} W_{W_k}^{j}$	$\sum_{j=1}^{m}\sum_{k=1}^{s} W_{S_k}^{j}$

ticular products,in the basic form of traditional enterprise input-output table, and according to the method of material flow cost accounting analysis, input-output table in enterprise manufacturing process based on the material flow balance can be constructed,as shown in the Table 1.

3.3 Material Flow Mass Balance Equation

While $\sum_{j=1}^{m} Q^j$ is the total mass of positive products in the period of Δt, the total mass of material input is equal to the total mass of material output, as shown in Equation (1).

$$\sum_{j=1}^{m}\sum_{i=1}^{n} I_{U_i}^j + \sum_{j=1}^{m}\sum_{i=1}^{n} I_{N_i}^j + \sum_{j=1}^{m}\sum_{i=1}^{n} I_{R_i}^j = \sum_{j=1}^{m} Q^j + \sum_{j=1}^{m}\sum_{i=1}^{n} O_{U_i}^j + \sum_{j=1}^{m}\sum_{i=1}^{n} O_{R_i}^j + \sum_{j=1}^{m}\sum_{k=1}^{g} W_{G_k}^j + \sum_{j=1}^{m}\sum_{k=1}^{w} W_{W_k}^j + \sum_{j=1}^{m}\sum_{k=1}^{s} W_{S_k}^j \quad (1)$$

According to the law of conservation of mass and following material flow mass balance equation,there is mass balance relationship in each row in input-output table. While Q^j is the total mass of No. j product in the period of Δt, the total mass of material input is equal to the total mass of material output, as shown in Equation (2).

$$\sum_{i=1}^{n} I_{U_i}^j + \sum_{i=1}^{n} I_{N_i}^j + \sum_{i=1}^{n} I_{R_i}^j = Q^j + \sum_{i=1}^{n} O_{U_i}^j + \sum_{i=1}^{n} O_{R_i}^j + \sum_{k=1}^{g} W_{G_k}^j + \sum_{k=1}^{w} W_{W_k}^j + \sum_{k=1}^{s} W_{S_k}^j \quad (2)$$

3.4 Environmental Cost Measurement Based on the Material Flow Balance

In the process of enterprises manufacturing, cost directly related with the environment can be divided into two categories: one is environmental protective cost, it is the disposal cost of waste generated in the production process, including waste gas disposal cost, waste water disposal cost and solid waste disposal cost; the other is environmental damage cost, it is the damage cost caused by the waste which is exhausted to the environment, including waste gas emission cost, waste water emission cost and solid waste emission cost.

(1) Measurement of Pollutant Disposal Cost

$$PDC^j = P_G^j T_G + P_w^j T_w + P_S^j T_S \quad (3)$$

PDC^j is the disposal cost of waste which is exhausted in the production of No. j product. P_G is the quantity of exhaust gas generated in the production process, T_G is the unit disposal cost of waste gas; P_W is the quantity of waste water generated in the production process, T_W is the unit disposal cost of waste water; P_S is the quantity of solid waste generated in the production process, T_S is the unit disposal cost of solid waste.

(2) Measurement of Residue Emission Cost

$$REC^j = REC_G^j + REC_W^j + REC_S^j = \sum_{k=1}^{g} W_{G_k}^j F_{G_k} + \sum_{k=1}^{g} W_{W_k}^j F_{W_k} + \sum_{k=1}^{g} W_{S_k}^j F_{S_k} \quad (4)$$

REC^j is the residue emission cost caused by the waste which is exhausted to the external environment in the production of No. j product, REC_G^j is waste gas emission cost, REC_W^j is waste water emission cost, REC_S^j is solid waste emission cost, F_{G_k} is the unit price of emission charge for category No.k waste gas which is exhausted to the external environment, F_{W_k} is the unit price of emission charge for category No.k waste water which is exhausted to the external environment, F_{S_k} is the unit price of emission charge for category No.k solid waste which is exhausted to the external environment.

4 Construction of Environmental Performance Measurement Model Based on the Material Flow Mass Balance Equation

4.1 Material Utilization Ratio Based on the Material Flow Mass Balance Equation

According to the Formula 1 and Formula 2, material utilization ratio can be measured based on the material flow mass balance equation.

(1)Material Conversion Ratio

$$MCR^j = Q^j \Big/ \left(\sum_{i=1}^{n} I_{U_i}^j + \sum_{i=1}^{n} I_{N_i}^j + \sum_{i=1}^{n} I_{R_i}^j \right) \quad (5)$$

MCR^j is a ratio of the total mass of product to the total mass of material input in the production of No. j product, to reflect the extent of material input converted into product.

(2)Material Reuse Ratio

$$MUR^j = \sum_{i=1}^{n} O_{U_i}^j \Big/ \left(\sum_{i=1}^{n} I_{U_i}^j + \sum_{i=1}^{n} I_{N_i}^j + \sum_{i=1}^{n} I_{R_i}^j \right) \quad (6)$$

MUR^j is a ratio of the total mass of reused material output to the total mass of material input in the production of No. j product, to reflect the extent of material reuse.

(3)Material Recycling Ratio

$$MRR^j = \sum_{i=1}^{n} O_{R_i}^j \Big/ \left(\sum_{i=1}^{n} I_{U_i}^j + \sum_{i=1}^{n} I_{N_i}^j + \sum_{i=1}^{n} I_{R_i}^j \right) \quad (7)$$

MRR^j is a ratio of the total mass of recycled material output which is provided by waste disposal centre to the total mass of material input in the production of No. j product, to reflect the extent of material regeneration.

4.2 Material Discard Ratio Based on the Material Flow Mass Balance Equation

(1)Waste Residue Ratio

$$WRR^j = \left(\sum_{k=1}^{g} W_{G_k}^j + \sum_{k=1}^{w} W_{W_k}^j + \sum_{k=1}^{s} W_{S_k}^j\right) \bigg/ \left(\sum_{i=1}^{n} I_{U_i}^j + \sum_{i=1}^{n} I_{N_i}^j + \sum_{i=1}^{n} I_{R_i}^j\right) \quad (8)$$

WRR^j is a ratio of the total mass of waste residue to the total mass of material input in the production of No. j product, to reflect the extent of waste residue.

(2)Waste Gas Residue Ratio

$$WGRR^j = \sum_{k=1}^{g} W_{G_k}^j \bigg/ \left(\sum_{i=1}^{n} I_{U_i}^j + \sum_{i=1}^{n} I_{N_i}^j + \sum_{i=1}^{n} I_{R_i}^j\right) \quad (9)$$

$WGRR^j$ is a ratio of the total mass of waste gas residueto the total mass of material inputin the production of No. j product, to reflect the extent of waste gas residue.

(3)Waste Water Residue Ratio

$$WWRR^j = \sum_{k=1}^{w} W_{W_k}^j \bigg/ \left(\sum_{i=1}^{n} I_{U_i}^j + \sum_{i=1}^{n} I_{N_i}^j + \sum_{i=1}^{n} I_{R_i}^j\right) \quad (10)$$

$WWRR^j$ is a ratio of the total mass ofwaste water residueto the total mass of material inputin the production of No. j product, to reflect the extent of waste water residue.

(4)Solid Waste Residue Ratio

$$SWRR^j = \sum_{k=1}^{s} W_{S_k}^j \bigg/ \left(\sum_{i=1}^{n} I_{U_i}^j + \sum_{i=1}^{n} I_{N_i}^j + \sum_{i=1}^{n} I_{R_i}^j\right) \quad (11)$$

$SWRR^j$ is a ratio of the total mass of solid waste residueto the total mass of material input in the production of No. j product, to reflect the extent of solid waste residue.

5 Empirical Analysis

5.1 Sample Selection and Data Sources

In this paper,EC Iron and Steel Co., Ltd. in Hubei province has been taken as an example of empirical research, and the related production data in 2013 has been collected. The data mainly comes from the production reports, industrial pollution disposal reports provided by environmental protection bureau, and statistical year book of Hubei province in 2013. Production activity data of EC Iron and Steel Co., Ltd. in 2013 has been compiled from collected raw data.

In 2013, the main material input of EC Iron and Steel Co., Ltd. is shown as the table 2.

In 2013, the main products of EC Iron and Steel Co., Ltd. is shown as the table 3.

In 2013, the main reused material output of EC Iron and Steel Co., Ltd. is shown as the table 4.

In 2013, the main recycled material output of EC Iron and Steel Co., Ltd. is shown as the table 5.

In 2013, the waste disposal cost of EC Iron and Steel Co., Ltd. is shown as the table 6.

Table.2 Main Material Inputof EC Iron and Steel Co., Ltd. in 2013

Material Input	Quantity
Iron Ore(ton)	4 370 700
Water Consumption(ton)	10 832 600
Including: New Water Input(ton)	9 706 000
Reused Water Input(ton)	48 156
Recycled Water Input(ton)	1 078 444
Coal Consumption(ton)	2 942 200
Including: Bunker Coal Consumption(ton)	788 100
Coke consumption(ton)	2 128 200
Bunker Coal Equivalent of Heat Energy Collection (ton)	25 900
Total Material Input(ton)	18 145 500

Note: Due to the relatively small amount, and in order to facilitate the calculation, other materials are not listed in Table 2.

Table.3 Main Products of EC Iron and Steel Co., Ltd. in 2013

Main Products	Quantity
steel products(ton)	2 791 110

Table.4 Main Reused Material Output of EC Iron and Steel Co., Ltd. in 2013

Reused Material Output	Quantity
Reused Water Output(ton)	48 156
Bunker Coal Equivalent of Thermal Energy Collection(ton)	25 900
Total (ton)	74 056

Note:The main reused material outputs of EC Iron and Steel Co., Ltd. are collected in water circulating system and thermal energy circulating system, the quantity of output per year remains unchanged before system upgrading.

Table.5 Main Recycled Material Output of EC Iron and Steel Co., Ltd. in 2013

Recycled Material Output	Quantity
Recycled Water Output(ton)	1 078 444
Recycled Chemical Material Output(ton)	15 962
Recycled Solid Material Output(ton)	2 457,477
Recycled Hazardous Material Output(ton)	2 980
Total (ton)	3 554 863

Table.6 Waste Disposal Cost of EC Iron and Steel Co., Ltd. in 2013

Waste	Quantity	Unit Disposal Cost	Waste Disposal Cost (yuan)
Waste Water	10 784 444(ton)	3.11(yuan/ ton)	33 539 621(yuan)
Waste Gas	14 576 121 (ten thousand m^3)	14.38(yuan/ten thousand m^3)	209 604 620 (yuan)

Note:Solid waste is used as raw material for industrial production, it is no need to consider the disposal cost.

In 2013, the water pollutants residue of EC Iron and Steel Co., Ltd. is shown as table 7.

Table.7 Water Pollutants Residue of EC Iron and Steel Co., Ltd. in 2013

Water Pollutants	Residue Quantity
COD(ton)	826.48
Ammonia Nitrogen (ton)	99.87
Petroleum (ton)	1.67
Volatile Phenol (ton)	1.209 0
Cyanide (ton)	0.180 00
Total (ton)	9 706 929.41

In 2013, the air pollutants residue of EC Iron and Steel Co., Ltd. is shown as table 8.

Table.8 Air Pollutants Residue of EC Iron and Steel Co., Ltd. in 2013

Air Pollutants	Residue Quantity
Sulphur Dioxide (ton)	12 139.79
Nitrogen Oxides (ton)	6 566.673
Smoke/Powder Dust(ton)	7 044
Total (ton)	25 750.463

In 2013, the solid waste residue of EC Iron and Steel Co., Ltd. is shown as table 9.

Table.9 Solid Waste Residue of EC Iron and Steel Co., Ltd. in 2013

Solid Waste	Residue Quantity
General Industrial Solid Waste(ton)	38 983
Hazardous Material Waste(ton)	0
Total (ton)	38 983

5.2 Environmental Costs Measurement of EC Iron and Steel Co., Ltd. in 2013

(1) Measurement of Pollutant Disposal Cost

According to Formula 3, in accordance, pollutant disposal cost can be calculated with the data presented in Table 6:

$$PDC^j = P_G^j T_G + P_w^j T_w + P_S^j T_S$$
$$= 14\,576\,121 \times 14.38 + 10\,784\,444 \times 3.11 + 0$$
$$= 243\,144\,241 \text{ yuan.}$$

(2) Measurement of Residue Emission Cost

According to China's "Sewage Collection Standard Management Approach", wastewater and waste gas sewage charges are measured based on pollution equivalent:

Amount of WasteWater Sewage Charges=0.7yuan × Sums of Pollution Equivalent Amount of 3 highest Water Pollutants Emissions;

Amount of Waste Gas Sewage Charges=0.6yuan × Sums of Pollution Equivalent Amount of 3 highest Air Pollutants Emissions.

Pollution equivalent amount is calculated as follows:

Pollution Equivalent Amount=Pollutant Emissions (kg)/Pollutant Equivalent Value (kg).

According to the data in Table 7 and China's "Sewage Collection Standard Management Approach”, the preparation of water pollutants equivalent amount of EC Iron and Steel Co., Ltd. in 2013 is shown as Table 10.

Table.10 Water Pollutants Equivalent Amount of EC Iron and Steel Co., Ltd. in 2013

Water Pollutants	Residue Quantity(kg)	Pollutant Equivalent Value (kg)	Pollution Equivalent Amount
COD	826 480	1.0	826 480
Ammonia Nitrogen	99 870	0.8	124 837.5
Petroleum	1 670	0.1	16 700

According to table 10,WasteWater Sewage Charges can be calculated. $REC_W^j = \sum_{k=1}^{g} W_{W_k}^j F_{W_k} = 677\,612.25$ yuan.

According to the data in Table 8 and China's "Sewage Collection Standard Management Approach", the preparation of air pollutants equivalent amount of EC Iron and Steel Co., Ltd. in 2013 is shown as Table 11.

Table.11 Air Pollutants Equivalent Amount of EC Iron and Steel Co., Ltd. in 2013

Air Pollutants	Residue Quantity(kg)	Pollutant Equivalent Value(kg)	Pollution Equivalent Amount
Sulphur Dioxide	12 139 790	0.95	12 778 726.32
Nitrogen Oxides	6 566 673	0.95	6 912 287.37
Smoke/Powder Dust	7 044 000	2	3 231 192.66

According to table 11,Waste Gas Sewage Charges can be calculated. $REC_G^j = \sum_{k=1}^{g} W_{G_k}^j F_{G_k} = 13\,753\,323.81$ yuan.

According to the data in Table 9 and China's "Sewage Collection Standard Management Approach”, preparation of solid waste sewage collection standards of EC Iron and Steel Co., Ltd. in 2013 is shown as Table 12.

Table.12 Solid Waste Sewage Collection Standards of EC Iron and Steel Co., Ltd. in 2013

Solid Waste	Residue Quantity (ton)	Sewage Collection Standards(yuan/ton)
General Industrial Solid Waste	38 983	25
Dangerous Waste	0	1 000

According to table 12,Solid Waste Sewage Charges can be calculated. $REC_S^j = \sum_{k=1}^{g} W_{S_k}^j F_{S_k} = 974\,575$ yuan.

The totalre sidue emission cost is: $REC^j = REC_G^j +$

$REC_W^j + REC_S^j$ =15 405 511.06yuan.

5.3 Environmental Performance Measurement of EC Iron and Steel Co., Ltd. in 2013

According to Formula 5, 6 and 7, material utilization ratiocan be calculated, as shown as Table 13.

Table.13 Material Utilization Ratio of EC Iron and Steel Co., Ltd. in 2013

Material Utilization Ratio	Computational Process	Ratio Value
Material Conversion Ratio	2 791 110/18 145 500	15.38%
Material Reuse Ratio	74 056/18 145 500	0.41%
Material Recycling Ratio	3 554 863/18 145 500	19.59%

According to Formula 8, 9, 10 and 11, material discard ratio can be calculated, as shown in Table 14.

Table.14 Material Discard Ratio of EC Iron and Steel Co., Ltd. in 2013

Material Discard Ratio	Computational Process	Ratio Value
Waste Residue Ratio	9 771 663/18 145 500	53.85%
Waste Gas Residue Ratio	25 750/18 145 500	0.14%
Waste Water Residue Ratio	9 706 929/18 145 500	53.50%
Solid Waste Residue Ratio	38 983/18 145 500	0.21%

5.4 Data Validation Based on the Material Flow Mass Balance Equation

According to Formula 1, the total material input and output can be calculated, as shown in Table 15.

Table.15 Material Input and Output of EC Iron and Steel Co., Ltd. in 2013

Category	Computational Process	Calculated Value
Total Input(ton)	4 370 700+10 832 600+ 2 942 200	18 145 500
Total Output(ton)	2 791 110+74 056+ 3 554 863+9 706 929.41 +25 750.463+38 983	16 191 692
Output-to-Input Ratio	16 191 692/18 145 500	89.23%

As shown in Table 15, there is a certain gap between the calculated results of total input and total output, and the output-to-input ratio is 89.23%. This indicates the existence of error in the statistics and the calculation process. Objectively speaking, it is neither possible nor necessary to reach the goal that total input is equal to total output absolutely.It should be acceptable that the empirical data exists 10.77% of error.

6 Conclusion

As an important subject in social and economic system, enterprise is the executor of resources allocation. The development and utilization of resources are mostly accomplished by enterprises. Chemical and physical changes occurring in the manufacturing process will bring pollution. Production and operation activities of enterprises are closely related with the environment. The measurement of environmental cost and environmental performance in the production and operation activities of enterprises would contribute to the evaluation of negative impacton natural environment. The introduction of the new economic value measurement would objectively reflect the actual value of production activities.

First, according to the flow condition and conversion of material, material flow measurement model in enterprise manufacturing process can be constructed to reflect the impact of production and operation activities on environment.

Second, environmental costs measurement model based on material flow balance can analyse environmental pollution caused in each link of production activities.Considering the existence of environmental costs, it no longer transfers the whole cost to the product cost account, but measures and controls environmental costs in the manufacturing process.

Third, environmental performance measurement model based on the material flow mass balance equation can perfectly reflect the environmental performance of production activities. It tracks and controls the overall material input by analysing material flow process, and reduces environmental impact and costs by analysing the causes of waste generated in the production process. In order to coordinate development of environment and economy, it can improve the management in production, reduce the emissions of waste,and increase productivity in enterprises.

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